

SERIAL NUMBER CHECKLIST

Entered
R04/19/05

JOB NO: 11726

CUSTOMER: STOCK

DATE: April 12, 2005

COMPLETED BY: Sean Colwell

90 HP Wellhead Booster

ITEM	MANUFACTURER	SERIAL #	CRN #	A #
Suction Scrubber V1	Chil-con	C250062A-1	L9760.213	530617
Primary Oil Separator V2	Chil-con	C250062B-1	L9758.213	530618
Secondary Oil Separator V3	Chil-Con	C250062C-1	L9799.213	530619
Blowcase V4	Toromont	N/A		
Air Cooler J15B	ACE Air-X-Hemphill	0502606-1 0502606-2	N/C T1101.231	
Oil Cooler	Viex	270751.13	L9315.123	NA
			Model	Arrangement
Compressor	Frick	0858NZ	XJF 151N ✓	NA
Compressor Engine	Caterpillar	N4F01229	G3304NA	222-9043
Control Panel	Murphy	M01-062-229	50-30-3503	NA
PSV-103 Relief Valve	Hydroseal	1004-2	060736.2C	245 ✓ PSI 327 SCFM
PSV-113 Relief Valve	Hydroseal	909-2	060736.2C	375 ✓ PSI 491 SCFM

TOROMONT

**TOROMONT
PROCESS
SYSTEMS**

STANDARD COMPRESSOR PACKAGE

TPS 90 hp

TPS 135 hp



TPS 200 hp

TPS 325 hp

**OPERATION & MAINTENANCE
MANUAL INSERT**

CONTACT NUMBERS



Calgary 4303 - 11th Street NE Calgary, AB T2E 6K4	Phone: (403) 517-1300 Fax: (403) 517-1323 (Parts) Fax: (403) 517-1323 (Service)
Red Deer 5304 - 39139 Hwy 2A Red Deer, AB T4S 2B3	Toll Free: (888) 343-8618 Phone: (403) 343-8618 Fax: (403) 343-1295
Edmonton 8835 – 53 rd Avenue Edmonton, AB T6E 5E9	Toll Free: (866) 440-6848 Phone: (780) 440-6848 Fax: (780) 466-7550
Fort St. John #3, 8715 – 100 th Ave Fort St. John, BC V1J 1W8	Toll Free: (888) 813-7853 Phone: (250) 787-7853 Fax: (250) 787-7648
Medicine Hat 557 18 th street S.W. Medicine Hat, AB T1A 8C4	Phone: (403) 526-1734 Fax: (403) 504-1462
Drumheller 801 Railway Ave S PO Box 2188 Drumheller, AB T0J 0Y0	Phone: (403) 823-8255 Fax: (403) 823-7928
Grande Prairie 11537 97th Ave Grande Prairie, AB T8V 5R9	Phone: (780) 513-2252 Fax: (780) 513-2270

1.0	MANUAL OVERVIEW	4
2.0	WARRANTY AND LIABILITY (NEW COMPONENTS ONLY)	5
3.0	SAFETY GUIDELINES	6
3.1	DANGER	6
3.2	WARNING	8
3.3	CAUTION	9
4.0	PROCESS DESCRIPTION	10
4.1	PROCESS SUMMARY	10
4.2	SUCTION SCRUBBER	11
4.3	BLOW-CASE (Optional)	12
4.4	NATURAL GAS COMPRESSION	13
4.5	COMPRESSOR OIL	15
4.6	OIL SYSTEM & COMPONENTS	16
4.7	GAS AFTER-COOLING	18
4.8	AUXILIARY SYSTEMS	19
5.0	CONTROLS	20
5.1	PANEL CONFIGURATION	20
5.2	SHUTDOWN SUMMARY SHEET	21
5.3	START PERMISSIVE CONTROL	22
5.4	SYSTEM PROTECTION	22
5.5	WARM UP PERIOD	22
5.6	PNEUMATIC	22
6.0	PRE-START UP CHECK LIST	23
6.1	PRESSURE TESTING AND PURGING	23
6.2	ALIGNMENT	23
6.3	OIL FILTER	23
6.4	OIL FLUSH	23
6.5	GLYCOL	24
6.6	COMPRESSOR LUBRICATION OIL	24
6.7	CONTROL SYSTEM	24
6.8	FINAL CHECK	24
7.0	INITIAL STARTING	25
7.1	PRE-START UP	25
7.2	START UP	25
7.3	RESTART ON SHUTDOWN	25
8.0	SYSTEM MAINTENANCE	26
8.1	BASIC PREVENTIVE MAINTENANCE RECOMMENDATIONS	26
9.0	WEEKLY OPERATING RECORD	27
10.0	TROUBLESHOOTING	28
10.1	SCREW COMPRESSOR SYSTEM	28
10.2	OIL SEPARATOR SYSTEM	30
10.3	FULL TIME OIL PUMP SYSTEM (IF APPLICABLE)	31
11.0	APPENDIX I	32
11.1	FRICK Vi REFERENCE	32
11.2	ARIEL Vi REFERENCE	34
11.3	ARIEL BALANCE LINE CHARTS	34
11.4	BACK PRESSURE CONTROL VALVE	39
12.0	APPENDIX II	40
12.1	RENTAL UNITS	40
12.2	FIELD PRE-SHIPMENT PREPARATION	41
12.3	MOUNTING SKID (Responsibility of End User)	42
13.0	APPENDIX III	44
13.1	SPECIAL INSTRUCTIONS	44

1.0 MANUAL OVERVIEW

INTRODUCTION

DANGER

IT IS IMPERATIVE THAT ONLY TRAINED PERSONNEL, WHO ARE FAMILIAR WITH THE SYSTEM, ARE ALLOWED TO CONTROL AND SERVICE THIS PACKAGE.

IF IN DOUBT OF ANY OPERATING PARAMETER OR FUNCTION OF THIS UNIT, OR ANY QUESTIONS CONCERNING THIS MANUAL, IMMEDIATELY CONTACT *TOROMONT PROCESS SYSTEMS*.

This compression package was designed and manufactured by Toromont Process Systems in Calgary, Alberta, Canada.

All piping, vessels, electrical components and controls are built to the applicable codes and standards.

A copy of this manual should always be accessible for reference to the operator, please refer to the appropriate section for a description of each system.

Look in Appendix III for special instructions, if your unit has any custom engineered features.

USE OF THIS MANUAL

The descriptions contained within this manual will include generic information that is common to **90 hp, 135 hp, 200 hp and 325 hp TPS** standard compression packages. Refer to the Process and Instrumentation Drawings and the Instrumentation Bill of Materials of your specific unit to establish the items that are included with your package. For general overviews of the system operation and design, refer to the appropriate section of this manual.

PROCESS AND OPERATING DESCRIPTION

Operating techniques that are discussed in this manual are basic instructions. It is the Field Operators responsibility to gain the skills and knowledge particular to each package.

PRE-START UP CHECKLIST

Used to identify a list of items, procedures and set points that require verification prior to start up.

INITIAL START UP

The system must be checked and verified to be safe and operating within normal parameters by a qualified **Toromont Process Systems** service representative, otherwise the product warranty becomes void. Please contact **Toromont Quality Compressor Services** to schedule this service.

SYSTEM MAINTENANCE

CAUTION

Under extreme operating conditions such as high or low operating temperatures or high S.G. gas, the routine maintenance schedule may have to be increased.

If the result of the oil sampling indicates a trend that the oil is being contaminated or is breaking down, the frequency of the oil sampling and analysis schedule ***must*** be increased

The maintenance schedule that is set out in this manual is a general description and may be subject to variation depending on the service of the particular unit. Maintaining performance records and conducting routine compressor and engine oil analysis are critical to ensure proper operation.

2.0 WARRANTY AND LIABILITY (NEW COMPONENTS ONLY)

The Company warrants only to the original purchaser that the apparatus delivered hereunder (the "apparatus") shall conform to the plans and specification given in connection with the sale of the apparatus for 12 months from the date it is first operated or 18 months from the date it is first shipped to the purchaser, whichever is earliest. This warranty does not cover equipment and accessories furnished by third parties which are warranted only to the extent of the third parties' warranty to the Company.

The original purchaser's exclusive remedy under this warranty is the repair of any part or parts of the apparatus, which in the Company's judgment did not conform to the said plans and specifications when shipped. This warranty shall be void unless said nonconformance is discovered before the expiration of this warranty and the Company is notified in writing and the nonconforming part delivered to the Company's factory, all delivery and return delivery transportation charges prepaid, within 30 days of such discovery. Repairs shall be made at the Company's factory without charge except for transportation. No allowances will be granted for repairs or alterations made by the original purchaser without the Company's written consent. In lieu of the foregoing remedy, the Company may, at its option, redesign, redevelop and/or replace the full purchase price thereof.

In the event that the Company in accordance with the express warranty and liability provisions contained herein shall be required to send an employee, agent or officer to any location other than the factory of the Company to observe, discover, assist, test, replace or repair the apparatus herein, the Company shall be entitled to charge to the original purchaser the travel expenses, any subsistence allowances and/or labour and service costs of the aforesaid employee, agent or officer.

In no event shall the Company be liable for any special, consequential, incidental, or indirect damages, or for any loss of use of or any damages to any installation, operation, or service into which the compressor and engine or parts thereof may be put, or for interest, work stoppage, impairment of other goods, loss by reason of shutdown or non operation, increased expenses of operation, cost of replacement power or equipment, claims of Company for service interruption, whether or not such loss or damage is based on contract, warranty, negligence, indemnity, strict liability, or otherwise.

Except as to the Company's liability respecting any performance guarantees specifically given in connection with the sale of the apparatus, the Company's liability arising out of the manufacture, sale or use of the apparatus shall under no circumstances exceed the cost of repairing or replacing defective parts as indicated herein and shall be limited in duration of this warranty.

The warranty and the Company's obligation hereunder are expressly in lieu of all other warranties, including but not limited to the implied warranties of merchantability, description and fitness for a particular purpose. All warranties which exceed aforementioned obligations are hereby disclaimed by the Company and excluded from this warranty.

In order to keep this warranty in effect, the original purchaser must have the apparatus maintained and serviced properly in accordance with the Company's instruction upon purchase.

It is expressly agreed and understood that this warranty will not cover any defect, damage or deterioration due to normal use, wear and tear and exposure or any damage or defects due to misuse, abuse, alteration, negligence, accident, flood, fire or acts of God or further damage or defects due to the repair of the apparatus by someone other than an authorized employee, agent or officer of the Company.

It is further understood and agreed that this warranty will not be applicable to any apparatus operated by the original purchaser which in the opinion of the Company constitutes or constituted unusual or hazardous operating condition.

3.0 SAFETY GUIDELINES

Safety is common sense. There are standard safety rules but each situation has its own particularities, which cannot always be covered by rules. Therefore, your experience and common sense will be your best guide to safety. Lack of attention to safety can result in: accidents, personal injury, reduction in efficiency and worse of all-LOSS OF LIFE. Watch for safety hazards and correct deficiencies promptly.


This compressor package has been designed and built to the highest safety standards possible, however, it must be realized that the safest machines are only as safe as the operator running it. With this in mind, please consider the following.

ALWAYS CONSIDER YOUR POSSIBLE PATH OF ESCAPE IF A FIRE OR EXPLOSION DOES TAKE PLACE. IN THE EVENT THAT PERSONNEL MAY NEED TO ESCAPE, KEEP THE AREA AROUND THE COMPRESSOR AS FREE AS POSSIBLE FROM MACHINERY, DEBRIS, FLUIDS AND PRODUCTION EQUIPMENT.


OBSERVE NON SMOKING RULE WHILE ON UNIT OR IN IMMEDIATE FACILITY OF UNIT

3.1 DANGER

3.1.1 Unit Modifications and Operation

	<i>All modifications to the unit have to be approved in writing by Toromont Process Systems.</i>	
	1.	Consult Toromont Process Systems prior to modifying the compressor package system. Improper modifications can invalidate vessel and piping codes and can pose potential hazards to personnel and equipment.
	2.	Do not tamper, modify or bypass package safety and shutdown equipment. This compressor package has been equipped with safety equipment, which will protect both equipment and personnel.
	3.	Do not exceed maximum allowable pressures and temperatures. Be sure all maximum allowable pressures and temperatures are not exceeded when starting, running, stopping or bypassing the compressor package. Serious equipment damage and personnel injury could result should maximum allowable pressures and temperatures be exceeded..

3.1.2 Air in System

	<u>AIR ENTERING SYSTEM</u>	
	HAZARD:	Possibility of explosion
	CAUSE:	1. Air entering system while shutdown 2. Unit draws a vacuum

PREVENTION:

- i. Purge system with inert gas (e.g. nitrogen) prior to Startup
- ii. A compressor operator must always keep in mind that his machine is handling a highly flammable substance (natural gas); and as long as the natural gas is not allowed to mix with air, it is relatively incombustible. Any gas (air and natural gas) flows from a high-pressure area to a low pressure area. Therefore, anytime the pressure in the gas system (e.g. main piping, bypass/vent piping, scrubbers) is lower than atmospheric pressure, the compressor is pulling a vacuum and air will try to enter. Be sure all possible points of entry are closed.

**BREAK IN PRESSURE LINE**

HAZARD: Possible Fire/explosion
 CAUSE: Unit vibrating

PREVENTION:

- i. If there is excessive vibration in the gas compressor package, **DO NOT** dismiss it as normal operation. Assess the severity of the problem and repair if necessary or contact Toromont Quality Compressor Service. Shut unit down until the cause of the vibration has been repaired.

3.1.3 Hot Work**TRAPPED COMBUSTIBLE LIQUIDS AND GASES**

HAZARD: Possible Fire/explosion
 CAUSE: 1. Enclosed area
 2. Spillage

DEFINITIONS

Hot work	<p>Cutting, welding, burning, air gouging, riveting, drilling, grinding and chipping, The use of non-classified electrical equipment Any work done on an combustion engine Any other work where flame is used or sparks are produce.</p>
Test:	<p>Any test performed to determine if any combustible/flammable substances are present in the atmosphere/tanks/under skid/enclosed areas that may cause an explosion. Testing is to be done by visual inspection and sampling.</p>

PREVENTION:

To ensure that no combustible liquids or gases are present in and around the unit follow the information shown below.

- i. Underneath skid:
 - Units come complete with checker plated flooring. The use of this solid flooring can trap combustible gases and liquids beneath the floor creating a potential explosion hazard AS PER SECTION 136 OH&S
 - Unit should be jacked up
 - All sections of the underside of the skid are to be tested.
 - Ground underneath skid is to be examined for any spillage of combustible liquids. Leave unit jacked up and ensure area is made safe, this eliminates the possibility of a **"contained" explosion**.
 - Underside of skid is to be purged with inert gas.
- ii. Surrounding area around skid:
 - Ground around skid is to be examined for any spillage of combustible liquids. If in doubt jack unit up and ensure area is made safe.
- iii. On Skid (tanks and enclosed areas):
 - All sections containing explosive gases are to be purged with an inert gas or filled with clean water and tested.
 - All sections containing explosive liquids are to be flushed out with clean water and tested.

EMPLOYER RESPONSIBILITY:

Despite anything in this part, an employer must ensure that hot work is not performed.

- a) In a location where flammable substance is or may be
 - i. In the atmosphere or
 - ii. Stored, handled, processed or used;
- b) On or in an installation or item of equipment that contains or may contain a flammable substance or its residue; or
- c) On a vessel that contains residue that may release flammable vapors or gases when exposed to heat until
 - i. Tests have been made that indicated the atmosphere is below the point at which it contains a mixture, with air and under atmospheric conditions, of a flammable substance exceeding 20% of that substance's lower explosive limit for gas or vapors, or the minimum ignitable concentration for dust; and
 - ii. Procedures have been implemented to ensure continuous safe performance of the hot work.

When tests are required during hot work, the employer must ensure that the test are made at regular intervals appropriate to the nature of the hazard association with the work being performed.

**LOOSE FITTING CLOTH**

HAZARD: Personal Injury

CAUSE: Clothing caught in machinery

PREVENTION:

- iii. When around machinery, loose clothing, neckties, rings wristwatches, bracelets, hand rags, etc. should not be worn.

**EXHAUST FUMES**

HAZARD: Asphyxiation

CAUSE: Improper Ventilation

PREVENTION:

- i. The exhaust products of an internal combustion engine are toxic and may cause injury or death if inhaled. All engine installations, especially those within a closed shelter or building, must be equipped and maintained with an exhaust discharge pipe directing exhaust gases to the outside air. A closed building or shelter must be adequately ventilated. A means of providing fresh air into a closed building or shelter is necessary.

3.2 WARNING**ALLOW COMPRESSOR PACKAGE TO COOL PRIOR TO SERVICING**

HAZARD: Burn

CAUSE: Hot equipment and liquids

PREVENTION:

- i. Always allow compressor package to cool before servicing.
- ii. Wait until engine and coolant have cooled down before removing radiator or surge tank caps. Always replace weak hoses, lines and fittings.

⚠ WARNING**SPECIALTY GASES.**

This compressor is designed to be operated with and compress sweet natural gas containing no hydrogen sulfide (H₂S), minimal amounts of nitrogen (n₂) and carbon dioxide (CO₂) and absolutely no air.

3.3 CAUTION**CAUTION**

1. Keep the compressor package clean.
2. Replace damaged fan blades promptly. If a fan blade or of fan jack-shaft is bent or damaged in any way, it should be replace. DO NOT attempt to repair or use the damaged parts. Fan assemblies must remain in proper balance. An unbalanced fan can fly apart during use and can create an extremely dangerous condition.
3. Safety equipment. Hearing protection, safety glasses, hard hats, safety shoes or boots and fire extinguishers are recommend and are required by some local, provincial or federal regulations and by some insurance carriers.

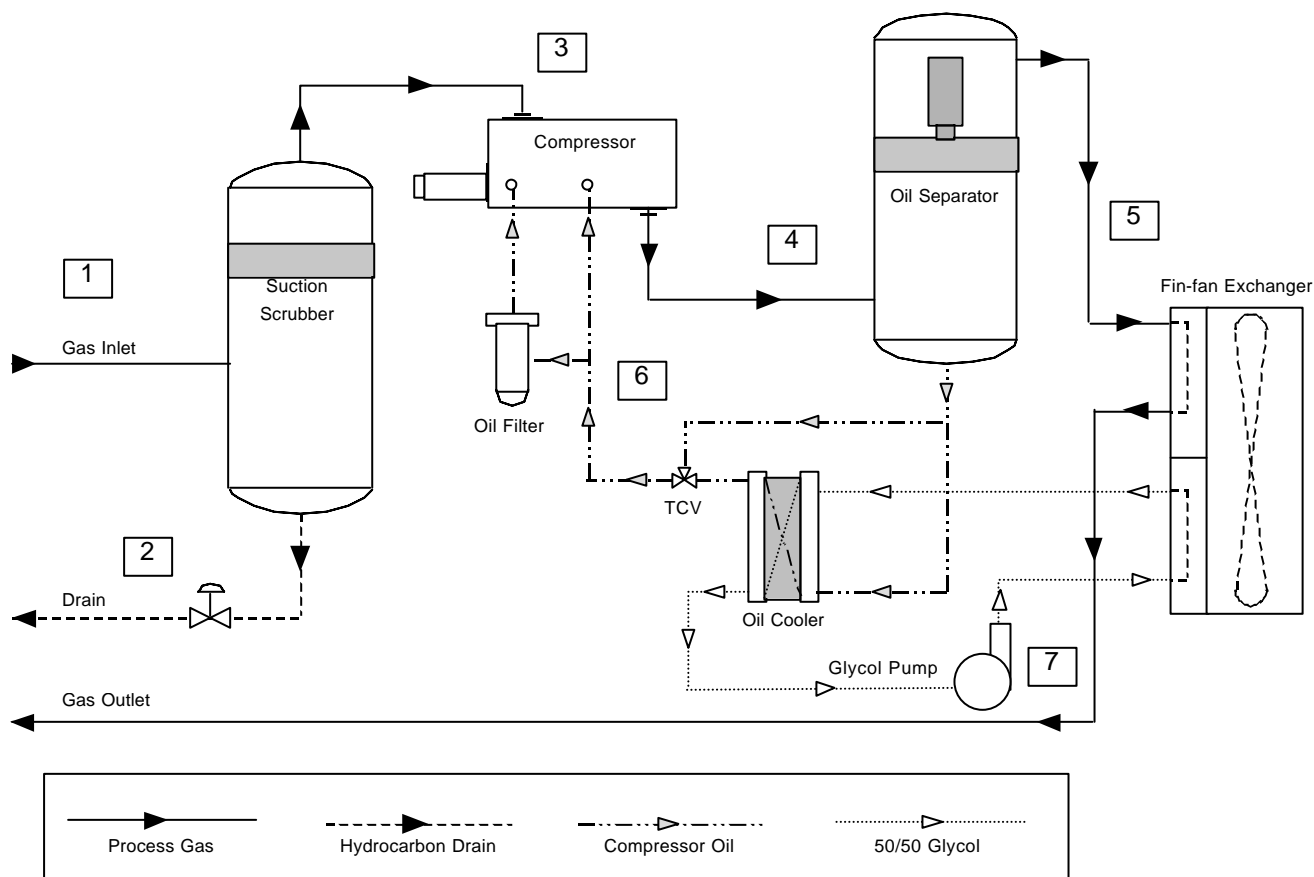
ADDITIONAL CAUTIONS, WARNINGS AND DANGERS CAN BE FOUND THROUGHOUT THIS MANUAL.

END USER AND OPERATORS MUST REFER TO THE RESPECTIVE OPERATION AND MAINTENANCE MANUAL OF THE INDIVIDUAL COMPONENTS SUPPLIED. INSTRUCTIONS IN THIS MANUAL DO NOT SUPERCEDE OR REPLACE OTHER MANUFACTURED GUIDELINES.

4.0 PROCESS DESCRIPTION

4.1 PROCESS SUMMARY

1. Inlet gas is fed through the suction scrubber to remove any free liquids or particulate.
2. Liquids are drained from the vessel to skid edge (blowcase option: liquid drains into blowcase) and the gas is routed to the compressor.
3. Compressed gas is mixed with lube oil during the compression cycle to meet the compressor lubrication requirements and absorb the heat of compression.
4. After compression, the oil/gas mixture is directed to the oil separator where the oil is removed from the gas stream and accumulated in the lower portion of the vessel.
5. Gas is directed to the fin-fan exchanger, where it is cooled before taken off skid to field piping.
6. Oil circulates within a closed-loop system. From the oil separator, oil enters the oil/glycol cooler, and then passes through the filter before returning to the compressor. Temperature of the lube oil returning to the compressor is kept constant by the thermostatic valve.
7. An engine driven pump circulates the glycol to the fin-fan exchanger, where additional heat of compression is removed (See 4.1 Figure 1).



4.1 Figure 1

4.2 SUCTION SCRUBBER

CAUTION

Liquids and condensates in the gas stream damage the compressor if not removed.

4.2.1 Description

A skid mounted ASME designed vessel for removing inlet liquids and particulate.

(See 4.2 Figure 1).

1. Inlet gas enters vessel and undergoes a change in direction and velocity. Majority of liquid and particulates separate from the gas due to centrifugal force and gravity.
2. Separated liquid falls to bottom of the vessel and automatically drains to skid edge.
(**Note:** End user is responsible for disposing of liquids.)

ATTENTION:

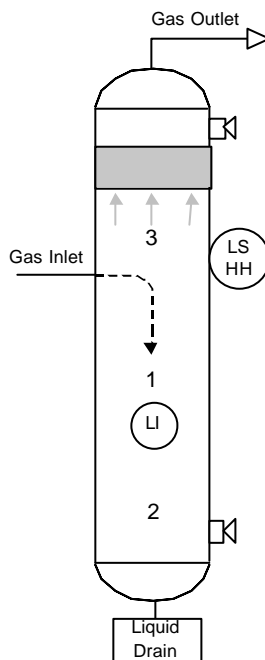
If the unit comes equipped with a blow-case (option), the liquid in the suction scrubber automatically drains into the blow-case. This is a different drain system than described in this section.

3. Gas passes through a stainless steel mesh pad where the remaining fluid mist is separated from the gas.

Standard design includes

- a) High-level shutdown.
- b) Level indicator or gauge.
- c) Auto liquid drain.

Note: Refer to P&I drawings & project BOM in this manual for vessel specifications.



4.2 Figure 1

4.3 BLOW-CASE (Optional)

4.3.1 Description

A skid mounted ASME designed vessel for collecting liquids from the suction scrubber, and discharging them into the gas outlet line on a cyclic basis. Compressor discharge gas, prior to the after-cooler, is used to pressurize the blow-case and direct the liquids into the discharge line. The ability to pressurize the blow-case above discharge line pressure is due to the pressure drop (pressure differential) across the after-cooler, piping and associated valves. The higher the differential pressure the faster the liquid is forced into the outlet.

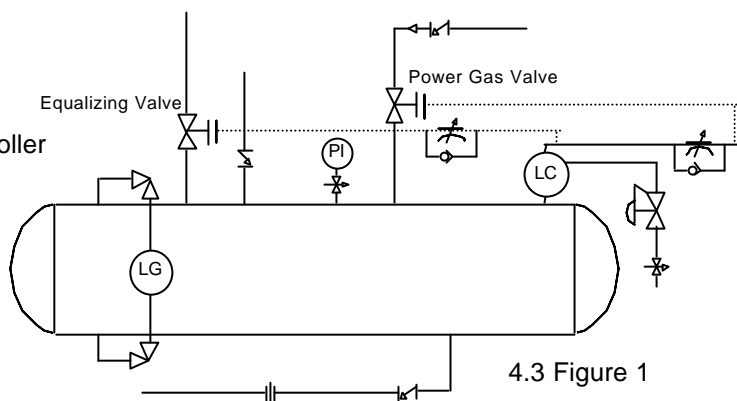
Note: End user responsible for discharge line tie-in and disposing of liquids.

ATTENTION:

At low compressor loads (low ΔP) the blow-case drain and fill cycle will take longer to occur. If high liquid removal is required, because of customer piping configurations, more ΔP may have to be created by throttling the discharge upstream of the liquid injection point.

Standard design includes

- a) Level indicator
- b) Pressure indicator
- c) Dual set-point level controller
 - i. Controls the drain and fill sequence of the blow-case



CAUTION

It is imperative that the Equalizing Valve is **never open** while the Power gas Valve is. (See 4.3 Figure 1)

4.3.2 Blow-case Draining Sequence

1. Maximum capacity of blow-case achieved.
2. Blow-case level controller sends pneumatic signal to control valves.
3. Pneumatic signal activates the drain sequence.
 - a) Equalizing valve to suction scrubber closes.
 - b) High-pressure gas valve opens (gas comes from upstream of after-cooler).
 - c) Check valve from suction scrubber to blow-case closes.
 - d) Blow-case pressurizes to compressor discharge pressure and liquid is forced out the drain line through the check valve into customer supplied drain system.
 - e) Blow-case minimum liquid level is achieved.
4. Once the blowcase minimum liquid level is reached, the level controller reverses the pneumatic signal returning equipment to fill sequence.

4.3.3 Blow-case Filling Sequence

1. Minimum capacity of blow-case achieved.
2. Blow-case level controller vents pneumatic signal to control valves.
 - a) High-pressure gas valve closes (gas comes from upstream of after-cooler).
 - b) Equalizing valve to suction scrubber opens.
3. Liquid from suction scrubber drains (via gravity) into blow-case through a check valve.

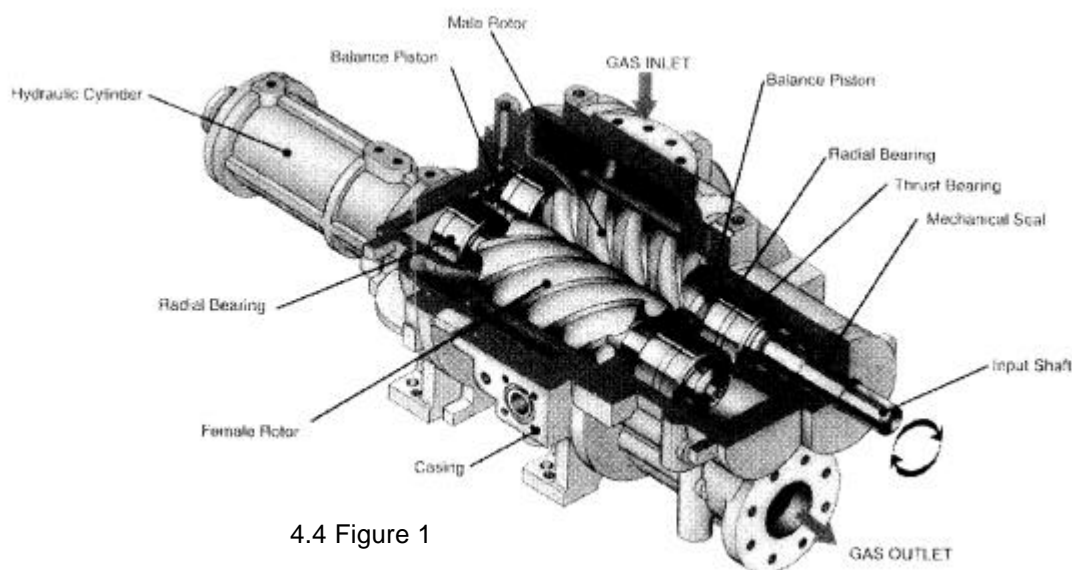
Note: Refer to P&I drawings & project BOM in this manual for vessel specifications.

4.4 NATURAL GAS COMPRESSION

WARNING

It is imperative to the operation of the compressor that all performance criteria be constantly monitored. These would include all system pressures, temperatures, levels and vibrations. The unit is provided with built in shutdown switches and monitors. These devices must be kept in proper working order at all times to ensure mechanical protection of the compressor

The compressor on this package is a positive displacement, oil flooded rotary screw. The screw compressor consists of two rotating parts, the male rotor (lobe) and female rotor (flute). The engine is coupled to and drives the male rotor, which in turn drives the female rotor. A screw compressor cutaway is included for component reference. (See 4.4 Figure 1)



4.4 Figure 1

4.4.1 Compressor Models (Standard Packages)

ATTENTION:

Your standard compression package comes equipped with **one** of the following screw compressors. (See 4.4 Table 1)

Note: Refer to P&I drawings & project BOM in this manual for compressor specifications.

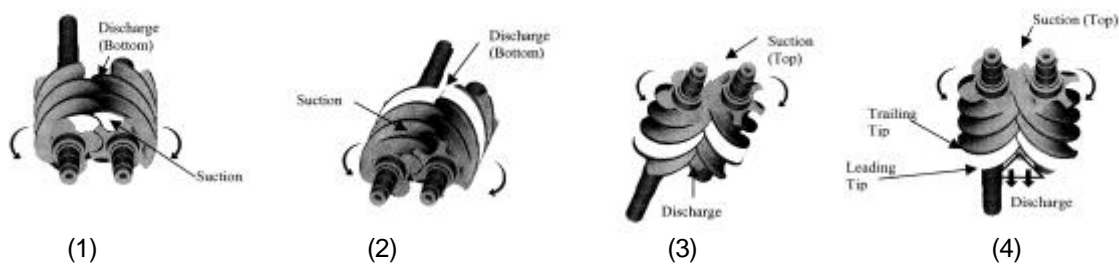
Toromont Standard Compression Packages					
Package Rating (Horsepower)	Compressor Manufacturer	Compressor Models			
90 hp (CAT 3304NA)	Frick	XJF-151A	XJF-151L	XJF-151M	XJF-151N
	Ariel	AR-166N			
135 hp (CAT 3306NA)	Frick	XJF-151A	XJF-151L	XJF-151M	XJF-151N
	Ariel	AR-208N			
200 hp (CAT 3306TA)	Frick	TDSH 193S		TDSH 193L	
	Frick	TDSH 233S	TDSH 233L	TDSH 233XL	
325 hp (CAT 3406TA)	Frick	TDSH 233S	TDSH 233L	TDSH 233XL	
	Frick	TDSH 283S	TDSH 283L	TDSH 283SX	

4.4 Table 1

4.4.2 Compression Process

Gas compression in a screw compressor is accomplished by trapping the gas in a pocket between the two rotors. The compressed gas is sealed by an oil film between tight clearances.

1. Rotors turn in an outward direction causing the male and female rotor to un-mesh at the suction port and create a pocket.
2. Gas fills the pocket until the maximum inter-lobe capacity is reached, at which point the pocket rotates past the suction port and traps the gas.
3. Continued rotor rotation reduces pocket size (volume), and increases gas pressure. During compression, the gas is closed off from the suction and discharge port.
4. Compression ends when the pocket containing the trapped gas uncovers the discharge port and releases the compressed gas to the discharge line.



4.4 Figure 2

4.4.3 Capacity Control

Compressor comes equipped with a step-less internal slide valve, operated manually with a hand-wheel. The slide valve can be used to adjust the compressor capacity from 25% to 100% of the maximum machine displacement. Turning the hand-wheel will mechanically move the slide valve.

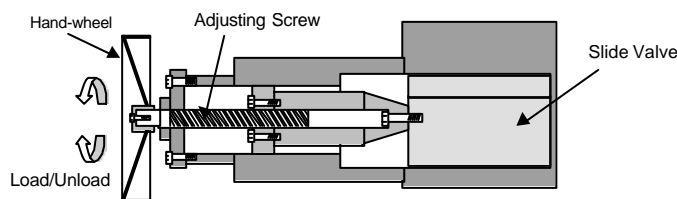
Loading Slide Valve (See 4.4 Figure 3).

When loading the compressor, slide valve moves away from discharge port and closes off an internal pocket on the bottom of the machine. This internal pocket acts as a re-circulation slot that controls the amount of gas being discharged from the machine (See 4.4 Figure 4).

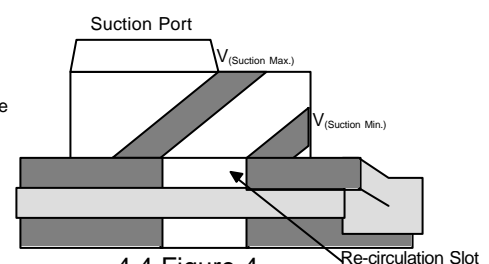
Frick XJF models:	Hand wheel rotated <u>counter-clockwise</u> .
Frick TDSH and Ariel AR models:	Hand wheel rotated <u>clockwise</u> .

ATTENTION:

Compressor capacity is directly related to compressor suction pressure. Without changing slide valve position and increasing suction pressure, the mass flow of gas through the compressor increases.



4.4 Figure 3



4.4 Figure 4

4.4.4 Internal Compression Ratio (Vi)

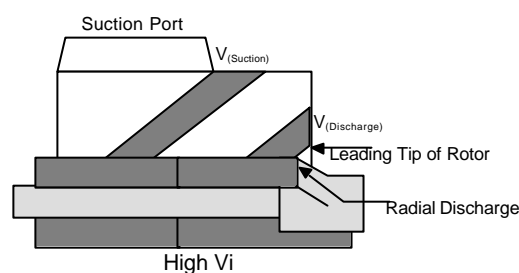
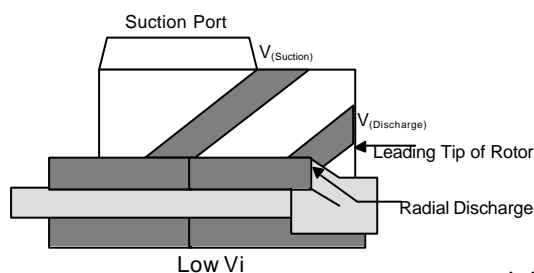
Frick and Ariel screw compressors are equipped with a (field adjustable) fixed internal compression ratio. The compressors are shipped with the most efficient internal compression ratio to suit the original compression package operating parameters. It may need adjustment in the field if actual operating conditions are different than first specified. The Vi controls the internal compression ratio by varying the duration of the compression cycle (See 4.4 Figure 5).

ATTENTION:

When choosing a Vi setting, it is always more economical to under-compress than over-compress. See Appendix I for Vi selection and procedure for adjusting the appropriate compressor model.

Vi Setting

Frick XJF models (90 & 135 hp)	Controlled hydraulically with oil galleries and gasket selections (See 11.1.1 Vi Selection)
Frick TDSH models (200 & 325 hp)	Controlled physically with mechanical ring spacers. Vi needs to be determined, a Vi-ring constructed and installed in the compressor by a <u>Toromont Quality Compressor Services</u> representative (See 11.1.2 Vi Selection).
Ariel AR models (90 & 135 hp)	Controlled physically with external Vi-spacers and associated hardware that are supplied with the compressor (See 11.2.1 Vi Selection).



4.4 Figure 5

4.5 COMPRESSOR OIL

CAUTION

Do not start or operate the compressor with cold oil. Oil within the **ENTIRE** oil circuit must be at least **room temperature** before the package may be started. Failure to provide warm oil can cause reduced oil flow and can damage or destroy the compressor. Refer to P&I drawings for minimum system ambient temperature.

ATTENTION:

The oil circuit is enclosed within the building for oil temperature considerations during cold weather starting. The unit is equipped with a catalytic heater that is powered from the fuel gas supply. Refer to P&I drawings for further details regarding lube-oil configuration.

For proper operation, the screw compressor requires large amounts of continuous lubrication to the rotating parts.

4.5.1 Purpose

1. Lubricates internal components:
 - a) Bearings
 - b) Rotors
 - c) Shaft seal
2. Seals internal clearances:
 - a) Between rotors
 - b) Between rotors and casing
3. Absorbs and removes the heat of compression.

4.5.2 Compressor Oil Injection Points

Depending on the type of compressor installed in the compression package, the number and location of oil injection points differ. All the oil injected into the compressor will migrate into the rotor area and be discharged from the compressor with the compressed gas.

Oil header and Main oil Injection

1. Header Oil injected into the bearings and seal area is filtered utilizing a **5-micron** rated filter.
NOTE: 200 HP only Oil header and main oil injection is filtered using a 5-micron filter.
2. Oil supplying the main oil injection port is not filtered. This oil passes through a globe valve, used to balance the oil flow, and an inline (**fine mesh**) strainer.

Note: 10-micron filters are available for packages with Frick compressors.

Frick Compressors

- a) Oil Header supplies oil to journal roller bearings, thrust roller bearings and shaft seal.
- b) Main oil injection to rotor injection port.

Ariel Compressors (all have separate tubing lines)

- a) Oil Header supplies oil to
 - i. Thrust roller bearings, discharge & suction hydrostatic bearings.
 - ii. Shaft seal & thrust counter balance.
- b) Main oil injection to rotor injection port.

4.6 OIL SYSTEM & COMPONENTS

4.6.1 Summary

Lubrication of the compressor is provided by a closed loop oil system. All oil supplied to compressor is mixed with compressed gas. Oil/gas mixture is carried out of the compressor to the oil separator where oil is removed from the gas stream and accumulated in the lower portion of vessel. Oil is then cooled and filtered before returning to the oil-header of the compressor.

4.6.2 Oil and Gas Separation

CAUTION

Heavy wet gases or gases with warm inlet temperatures can be considered **high dew point gases** and will damage the compressor if proper precautions are not taken. **High dew point gas** can condense in the compression cycle and rapidly contaminate the compressor oil. Please contact **Toromont Process Systems** if **high dew points** are a concern. The compressor warranty is void if failure occurs due to oil contamination. A high level shutdown can be installed in the oil separator to minimize this damage, but it is best to avoid free liquid in the discharge gas.

ATTENTION:

200 hp and 325 hp packages only have one oil separator vessel; the primary and secondary stages are combined. Vessel has the same components and sections

Package comes complete with a skid mounted ASME design Primary and Secondary Oil Separator (*See 4.6 Figure 1 and 4.6 Figure 2 respectively*). Oil separators remove the lube oil from the compressed gas with a minimum amount of pressure drop. The oil separator design, given normal separation levels, will result in a reduction of the oil content in the discharge gas to 10 PPM (aerosol) or better. The lower portion of the primary oil separator acts as the oil reservoir for the lubrication circuit.

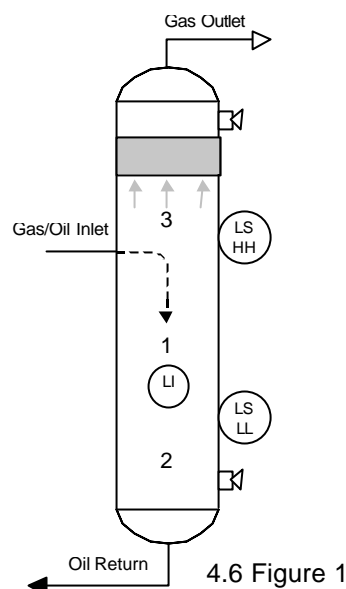
Primary Oil Separator

1. Oil/gas mixture enters vessel and undergoes change in direction and velocity. Majority of oil is separated from gas by centrifugal force and gravity.
2. Oil collected in bottom of oil separator has sufficient retention time for gas bubbles to escape before re-introducing oil back into circuit.
3. Oil/gas haze is filtered through a stainless steel mesh pad where more lube oil is recovered.

Standard design includes

- a) Level indicator or gauge
- b) Low level shutdown
- c) High level shutdown (**90 and 135 hp packages only**)

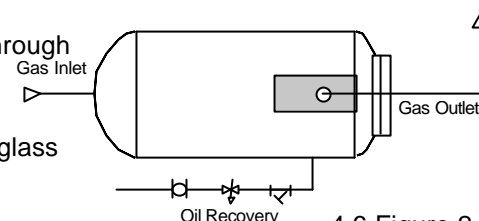
Note: Refer to P&I drawings and project BOM in this manual for vessel specifications.



4.6 Figure 1

Secondary Oil Separator

1. Oil droplets are formed when oil/gas mist passes through the coalescing filter element. An oil recovery line returns this oil to the compressor suction port.
2. Oil recovery line contains a needle valve and sight glass for controlling return flow rate (See 4.6 Figure 2).



4.6 Figure 2

CAUTION

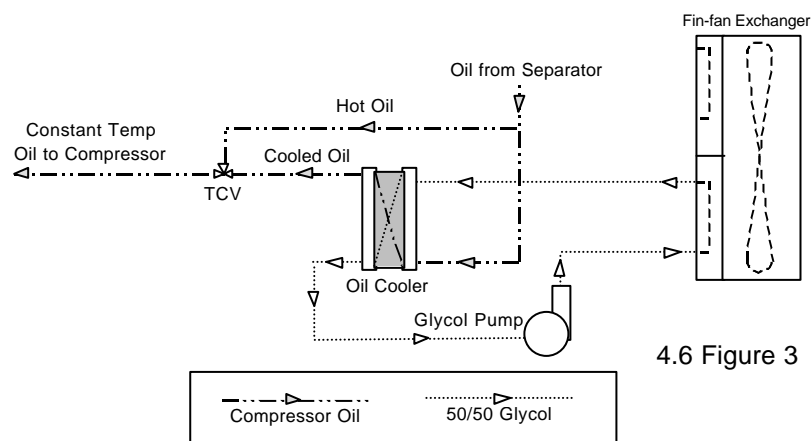
Needle valve on the oil recovery line should ONLY be open enough to keep the coalescing section of the secondary oil separator free from accumulated lube oil.

4.6.3 Oil Cooler

Gas compression package is supplied with a plate and frame type oil cooler that removes heat of compression from the lubrication oil. Oil cooler is mounted inside the building and utilizes a closed-loop circuit containing a 50/50 glycol media for indirect heat transfer. Glycol is circulated through the system by an engine driven pump, and heat transferred to the glycol is removed as it passes through a fin-fan exchanger (See 4.6 Figure 3).

4.6.4 Oil Circuit Temperature Control

Compressor oil temperature is controlled by a 3-way thermostatic valve. The thermostat maintains a constant oil supply temperature by mixing hot bypass oil with cool oil exiting the oil cooler. Oil supply is protected with a high temperature shutdown (See 4.6 Figure 3).



4.6 Figure 3

4.6.5 Oil Circulation

CAUTION

It is imperative that proper oil flow to the compressor is always maintained.

Frick Compressors

Differential pressure between suction and discharge drives the compressor oil circuit. Two differential pressure measurements are monitored to ensure proper oil flow to compressor.

Discharge pressure over main oil header

Measures difference between high-pressure side (oil separator) and low-pressure side (main oil header). Differential pressure **MUST** be less than 30 psi at all times.

ATTENTION:

A shutdown on this fault will indicate that the oil filter is dirty and requires replacing.

Oil header pressure over main oil injection

Pressure difference between oil going into the rotor area and oil going to compressor bearings is monitored. Main oil header pressure **MUST** be **15 psi greater** than the main oil injection to ensure proper oil flow to the bearings and shaft seal.

Ariel Compressors

Oil is supplied to the **compressor bearings** by using a compressor mounted full-time oil pump. Oil for **main oil injection** is driven by differential pressure. To ensure sufficient and constant oil pressure to the system, the following safeguard has been implemented.

ATTENTION:

A bypass has been installed around the oil pump to allow differential pressure to drive the oil circuit when the pump is not required. This only occurs at high differential pressure conditions. A pressure relief valve protects the oil pump. Normal pump output is regulated at **45 psi above** compressor discharge pressure.

Oil differential pressure across the main oil supply

Measures the difference between the high-pressure side (main oil header) and the low-pressure side (scavenger oil port). Differential pressure **MUST** be **greater than 95 psi** at all times to ensure that compressor is receiving sufficient oil flow to bearings and shaft seal.

4.7 GAS AFTER-COOLING

After exiting the coalescing section of the oil separator, process gas passes through a section of the fin-fan cooler where it is cooled to 120 °F by ambient air. The cooler fan is belt driven from the engine crankshaft pulley. Gas leaves cooler and is discharged to skid edge through the discharge line running on or below the skid deck.

4.8 AUXILIARY SYSTEMS

4.8.1 Cooling

90 and 135 hp Units

Engine jacket water and **compressor oil cooling** are provided by a closed-loop water/glycol circuit contained within the building. System utilizes the engine's main water pump to circulate coolant to the fin-fan cooler, then to compressor oil cooler before returning to engine. Temperature is controlled by a 3-way thermostatic valve within the engine.

Standard design includes

- a) Pressurized coolant make-up/expansion tank.
- b) Low level shutdown.
- c) High jacket water temp shutdown.

Note: Refer to P&I drawings & project BOM in this manual for tank specifications.

200 and 325 hp Units

1. **Engine jacket water-cooling** is provided by a closed-loop water/glycol circuit contained within the building. The engine jacket water cooling utilizes the engine's main water pump to circulate the coolant between the engine and fin-fan cooler. The temperature is controlled by a 3-way thermostatic valve within the engine.
2. **Engine turbo/after-cooler** and **compressor oil cooling** is also provided by a closed-loop water/glycol circuit contained within the building. The circuit uses an auxiliary engine mounted pump to circulate the coolant from the engine turbo/after-cooler, to the compressor oil cooler and then to the fin-fan exchanger before returning to the engine.

Standard design includes

- a) Two pressurized coolant make-up/expansion tanks.
- b) High jacket water temp shutdown.
- c) High manifold temp shutdown.
- d) Low level shutdowns. (2)

Note: Refer to P&I drawings & project BOM in this manual for tank specifications.

4.8.2 Fuel and Start Gas

CAUTION

Do not operate fuel and instrument gas from a **sour gas** supply. A separate sweet fuel or instrument supply **MUST** be installed.

ATTENTION:

High-pressure fuel gas take off is a 4" flanged pipe to aid in liquid knockout.

Both fuel and start gas are supplied from the process. Valve selectable, the fuel gas is drawn from either the suction or cooled discharge streams. Building heater also runs on this supply. The start gas is taken down stream of the oil separator from compressor discharge.

Standard design includes

- a) Fuel filter.
- b) Building heater(s).
- c) Fuel shut-off valve.
- d) Low pressure starter.
- e) Primary and secondary regulators.

Note: Refer to P&I drawings & project BOM in this manual for component specifications.

5.0 CONTROLS

A Murphymatic control panel protects compressor unit in the event of a malfunction. This panel incorporates a LCDT digital TATTLETALE control system, which is an integrated fault annunciator and alarm/shutdown controller, designed to protect engines and associated equipment on package.

In the case of a shutdown condition on the package, the LCDT panel will indicate the parameter that has caused a shutdown. The panel is capable of 47 shutdowns or alarms, 15 of which have timed start up override.

5.1 PANEL CONFIGURATION

5.1.1 Control Panel Power Requirements

TPS 90, 135 and 200 hp

The Panel on the package is powered by an *engine driven magneto*.

TPS 325 hp

The panel on the package is powered from the electronic ignition on the engine. Units are equipped with an electronic ignition and will require a **24VDC power supply** (*Customer Supplied*) or by the addition of power generation on the engine. Please contact **Toromont Process Systems** if this is required. A shutdown input is provided for this purpose.

5.1.2 Gas Detection

Gas detection is provided **by others** as required by site area classifications, operating procedures and local authorities. Area classification **must** be determined by Enduser/Employer, not by the equipment packager.

5.1.3 Shutdown/Logic Functions

Shutdown functions consist of sensors and indicators or switch-gages mounted in the panel. The sensor measures the condition of a point in the process and the indicator reads the condition of that point.

The Murphymatic system is a non- incendive shutdown and monitoring system designed to be used with sensors and switches, which have normally open or normally closed contacts.

The panel is suitable for Class I, Div II, Group D areas with the inclusion of an explosion proof power supply. A battery is supplied within the panel to maintain all settings and electronics during a shutdown.

5.1.4 Inputs

The control system provides a number of discrete inputs such as shutdown switches for pressure, temperature, level and vibration. Since the LCDT panel does not have the ability to display the condition of a monitored point, switch-gages perform this task.

ATTENTION:

If an optional remote shutdown is provided, a dry set of contacts is required from an external source.

5.1.5 Outputs

The panel will control the fuel valve and an ignition ground, which can be configured to shut the fuel valve 3 seconds before the ignition is grounded. This is used to purge the fuel system downstream of the isolation valve.

ATTENTION:

Automatic capacity control of the screw compressor is not possible with the standard Murphymatic panel. A separate pneumatic control is required to control the engine speed and loading of the screw compressor

5.1.6 Shutdowns

The control system on this package is equipped with multiple shutdowns to protect the equipment from damage. The shutdowns are separated into two categories:

1. **Class "A":** Shutdowns MUST be clear prior to any output function being enabled. There is no bypass time delay provided on class "A" shutdowns.
2. **Class "B":** Shutdowns will be bypassed for a pre-set time period. The shutdowns will become active when the time period has lapsed and all class "B" conditions are satisfied.

ATTENTION:

Class "B" shutdowns allow for start up with ample time to stabilize the system.

5.2 SHUTDOWN SUMMARY SHEET

Equipment	Shutdown/Alarm	90 & 135 hp	200 & 325 hp
Compressor	Local Emergency Stop	A	A
Compressor	Remote Emergency Stop	A*	A*
Compressor	Fire Detection	A*	A*
Compressor	Gas Detection	A*	A*
Compressor	High oil level	A	A*
Compressor	Low oil level	A	A
Engine	Low oil level	A	A
Engine	Low jacket water level	A	A
Engine	Low turbo/oil cooling water level		A
Suction Scrubber	High liquid level	A	A
Engine	Over-speed	A	A
Compressor	High suction pressure	B	B
Compressor	Low suction pressure	A	A
Compressor	Low oil differential pressure	B	B
Compressor	High discharge pressure	A	A
Compressor	Low discharge pressure	B	B
Compressor	High discharge to oil header pressure	B**	B
Engine	Low oil pressure	B	B
Compressor	High discharge temperature	A	B
Compressor	High oil temperature	A	B
Engine	High jacket water temperature	B	B
Engine	High manifold temperature		B
Compressor	High vibration		A
Cooler	High vibration		A
Engine	High vibration	A	A

* Optional

** Frick compressors only

5.3 START PERMISSIVE CONTROL

CAUTION

1. To prevent driver overload on start up, ensure compressor is at minimum load.
2. Do not crank the engine for more than 20 seconds on failed start attempts.

5.3.1 Perform the following:

1. Clear all "A" class shutdowns.
2. Unload compressor with hand-wheel located at end of slide valve.
3. Complete pre-lube requirements (*if so equipped*).
4. Reset panel and fuel shut-off valve.
5. Open start gas valve to engage starter.

5.4 SYSTEM PROTECTION

The control system will monitor operating conditions to ensure system performance is within safe and normal operating limits.

Note: Set-points may vary due to design conditions.

Refer to P&I drawings for your specific unit to confirm protection system set-points.

5.4.1 Compressor protection

1. Suction pressure is limited between 5 and 90 psig by a dual acting switch-gauge. Inlet Pressure Safety Valve is sized for fire and set at 245 psig.
2. Discharge pressure is limited between 10 and 300 psig by a dual acting switch-gauge. Discharge Pressure Safety Valve is sized for compressor maximum flow and set at 375 psig.

Frick Compressors

Oil Header Pressure

Must be within 30 psig of the system discharge pressure, this ensures that the oil system is functioning properly, all valves are open and the oil filter is not plugged.

Pressure at Main Oil Header

Must be at least 15 psig greater than oil injection pressure, this will ensure adequate oil flow to bearings and shaft seal for safe operation.

Ariel Compressors

Differential pressure between the main oil header (high side) and scavenge oil port (low side) **MUST** be greater than 95 psig at all times. This will ensure adequate oil flow to bearings and shaft seal for safe operation.

5.5 WARM UP PERIOD

The start up sequence includes a warm up period for the engine.

1. Start the engine with the capacity of the compressor completely unloaded.
2. Allow the engine to warm to operating temperature before loading the system.

ATTENTION:

The engine manufacturer has specified the low idle speed for this particular model. The idle should only be increased when the jacket water temperature has reached a minimum of 125°F (52°C).

5.6 PNEUMATIC

All pneumatic devices are supplied with instrument gas. This gas supply **MUST** be sweet process gas, fuel gas or compressed air.

CAUTION

DO NOT USE SOUR GAS.

6.0 PRE-START UP CHECK LIST

6.1 PRESSURE TESTING AND PURGING

When all the appropriate lines have been connected to the unit, it should be pneumatically leak tested with air or nitrogen.

1. The unit has been thoroughly pressure tested prior to shipment. Leaks can occur due to transit and other items that may cause piping strain. It is the responsibility of the customer to ensure a leak test is performed at site.

DANGER

TO AVOID AN EXPLOSION, ALL THE AIR MUST BE PURGED FROM THE SYSTEM USING AN INERT OR PROCESS GAS PRIOR TO START UP

A positive pressure is to be maintained on the complete system at all times while starting, idling and running.

6.2 ALIGNMENT

The compressor drive shaft coupling and belt drive system have been aligned prior to shipment. The alignment may shift due to:

1. Loading, unloading and transit.
2. Settling of the main skid base on its support.

Therefore, the following MUST be completed prior to commissioning:

1. A final compressor alignment.
2. A final alignment and examination of all belts.
 - a) An idler located under belt guard will adjust the belt tension on the fin-fan cooler.
3. Belts should be checked for excess vibration, noise and slippage.

Note: The unit may be equipped with a jackshaft and/or belt driven auxiliary glycol pump, if this is the case:

1. The belts on both ends of the jackshaft must be periodically checked for tension and/or wear.
2. The belt driving the glycol pump is adjusted by shifting the pump body.

WARNING

THE ENGINE MUST BE SHUT OFF TO TIGHTEN THE BELTS. UNDER NO CIRCUMSTANCE IS THE SYSTEM TO BE OPERATED WITHOUT THE BELT GUARDS INSTALLED AND SECURED.

ATTENTION:

A hot alignment should be completed on the compressor and belt drive systems after 500 hours run-time. Recheck all hold bolts at this time.

6.3 OIL FILTER

The oil filter has been installed in the housing prior to shipping.

ATTENTION:

The oil filter should be changed when the pressure differential exceeds 7 psi (50 kPa) with the compressor oil at operating temperature.

6.4 OIL FLUSH

Prior to shipping, an oil flush was completed to remove all fabrication debris between the filter and compressor.

CAUTION

If there is reason to suspect that debris have contaminated the compressor oil or associated piping, an oil flush MUST be performed prior to restarting. Consult **Toromont Quality Compressor Services** for the proper oil flush procedure.

6.5 GLYCOL

Glycol loop has been filled with 50/50 water/glycol coolant prior to shipping. There is a high possibility that air will be trapped in the system; therefore, the cooling system MUST be purged of air before commissioning.

1. Open all appropriate valves in the glycol loop.
2. Charge the system from a low point and bleed air from any possible high spots.
3. Pump glycol into the system until a level is established in the expansion/surge tank.
4. Ensure the engine and cooler high points are void of trapped air.

ATTENTION:

Listen for pump cavitation and watch for glycol flow during the first run test.

6.6 COMPRESSOR LUBRICATION OIL

Following an oil flush, utilizing the same type of lubricant used for normal operation:

1. Charge the system to the proper operating level.
2. Use the catalytic heater to warm the oil, building and equipment.
3. Open all appropriate valves.

CAUTION

Cold oil will have a high viscosity resulting in a low oil flow condition that will damage the compressor. Warm compressor oil to 60°F before starting unit.

ATTENTION:

Do not overfill the oil separator. High levels impede oil/gas separation, cause foaming of the oil and result in excessive oil carry over.

Note: Refer to P&I drawings for you specific unit to confirm the proper fluid quantities.

6.7 CONTROL SYSTEM

The control system logic and wiring must be checked before commissioning.

1. Ensure ALL ELECTRICAL SEALS have been poured.
2. Preset and test all safety systems for proper functioning.
 - a) This includes a complete point-to-point function test of the panel, end devices and associated wiring.

⚠ DANGER

IF IT HAS BEEN DETERMINED THAT FIRE AND/OR GAS DETECTION IS REQUIRED, THEN FIRE AND/OR GAS MONITORING SYSTEMS MUST BE ACTIVE AND OPERATIONAL BEFORE PROCEEDING TO COMMISSION THE UNIT. (CUSTOMER SUPPLIED)

6.8 FINAL CHECK

⚠ WARNING

Visually inspect unit before starting. Prior to starting, walk around the compressor package and visually inspect the unit for loose or broken components, tools, open valves, missing equipment etc.

7.0 INITIAL STARTING

Initial start up and running operation is based on all pre-commissioning procedures being completed.

7.1 PRE-START UP

1. Check compressor oil, engine oil and glycol for proper levels.
2. Lubricate all bearings.
3. Warm compressor oil and equipment to room temperature.
4. Check that all valves are in the correct position.
5. Check that all level and pressure controls are at the proper settings.
6. Pre-lube engine and compressor (*if applicable for your specific unit*).
7. Clear area and equipment of loose items.

7.2 START UP

1. Unload the compressor.
2. Reset the control panel.
3. Reset the fuel shut-off valve.
 - a) Valve will automatically close on unit shutdown. It must be manually opened.
 - b) Ignition system is automatically activated when engine reaches minimum RPM.
4. Allow engine to idle until the jacket water temperature reaches 125°F, typically about 10 minutes. During warm up the compressor must be unloaded with the bypass valve open and adjusted to maintain operation.
5. Close the bypass valve and manually load compressor to 50% capacity.
6. Operate the compressor at this capacity and check the following items:
 - a) Compressor oil supply pressure and temperature.
 - b) Oil filter pressure differential.
 - c) Compressor oil level.
 - d) Compressor shaft seal for leakage.
 - e) Engine oil pressure and temperature.
 - f) Engine jacket water level and temperature.
 - g) Turbo water level and temperature (**200 hp and 325 hp units only**)
 - h) Suction pressure.
 - i) Discharge pressure and temperature.
 - j) Check engine, compressor, and fan for noise and vibration.
7. Load compressor and engine until discharge pressure is at desired operating pressure.
8. Monitor operation, check suction scrubber level control system and adjust oil separator return system.
9. Monitor operation until all systems are stable.

ATTENTION: The unit can now be shut down and restarted as required.

7.3 RESTART ON SHUTDOWN

In the event of a compressor shutdown the cause must be corrected prior to a restart. The compressor can then be restarted and slowly loaded.



DO NOT RESTART A COMPRESSOR AFTER A FAULT SHUTDOWN WITHOUT FIRST DETERMINING THE CAUSE OF THE SHUTDOWN.

8.0 SYSTEM MAINTENANCE

Unit is designed to operate automatically with built in safety controls to protect equipment in case of malfunction. It requires only routine inspection. However, maintenance of an adequate log will indicate small changes in performance and provide early warning of possible malfunction. A sample weekly log sheet is enclosed. For packages with multiple compressors, a log for each compression system and each compressor should be maintained.

ATTENTION:

Following table is for **Screw Compressors Only**. Refer to manufacturer's recommended maintenance (in this manual) for other components of the system.

8.1 BASIC PREVENTIVE MAINTENANCE RECOMMENDATIONS

ATTENTION:

Analyze daily records to determine if performance is varying from within design limits. **Make corrections as soon as possible.**

WARNING

Safety controls, relief valves and rotating equipment should be checked annually by qualified personnel.

1. Take precautions to avoid damage caused by liquid expansion in lines isolated by positive shut-off valves.
2. Ensure that all valves are in there normal operating position.
3. Never close valves on pressure operated safety controls or "shunt out" electrical control circuits.

CAUTION

Use manufacturer's recommended fluids and lubricants. Perform monthly oil analysis. **Increase frequency under extreme conditions.**

MAINTENANCE (Screw Compressor)	HOURS OF OPERATION (MAXIMUM)								
	500	1000	5000	10000	15000	20000	25000	30000	
Change Oil			✓					✓	EVERY 30000 HOURS THEREAFTER OR AS PER OIL ANALYSIS
Change Filter	✓		✓	✓	✓	✓	✓	✓	EVERY 5000 HOURS THEREAFTER OR AS PER OIL ANALYSIS
Clean Liquid Strainers	✓		✓	✓		✓		✓	EVERY 10000 HOURS THEREAFTER OR AS PER OIL ANALYSIS
Change Coalescing Elements								✓	EVERY 30000 HOURS THEREAFTER OR AS PER OIL ANALYSIS
Check & Clean Suction Screen	✓	✓	✓	✓		✓		✓	EVERY 10000 HOURS THEREAFTER OR AS PER OIL ANALYSIS
Check Alignment	✓		✓	✓		✓		✓	EVERY 10000 HOURS THEREAFTER
Check Coupling	✓		✓	✓		✓		✓	EVERY 10000 HOURS THEREAFTER
Check Temperature Pressure Calibration	✓	✓	✓	✓		✓		✓	EVERY 10000 HOURS THEREAFTER
Check & Calibrate All Shutdowns	EVERY 6 MONTH								
Oil Analysis	MONTHLY								
Replace Shaft Seal					✖		⊙	↻	
Inspect Compressor					✖		⊙	↻	
15000 Hours:	✖	GAS PROCESSING – HIGH OPERATION PRESSURES							
25000 Hours:	⊙	HIGH VOLUME DUTY							
30000 Hours	↻	LOW BOOSTER DUTY							

9.0 WEEKLY OPERATING RECORD

COMPRESSOR WEEKLY OPERATING REPORT								
Company:				Week of 20 _____				
Location:				Unit #:				
Item	Units	Sunday	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday
Compressor Suction Pressure								
Compressor Suction Temperature								
Compressor Discharge Pressure								
Compressor Discharge Temperature								
Compressor Oil Pressure								
Balance Line Pressure (Ariel Comp. Only)								
Compressor Oil Filter Differential Pressure								
Ambient Temperature								
Compressor Oil Temperature		In						
		Out						
Engine Oil Temperature		In						
		Out						
Engine Jacket Water Temperature		In						
		Out						
Engine Turbo Water Temperature (200 & 325 HP Only)		In						
		Out						
Engine Oil Pressure								
Fuel Gas Pressure								
Oil Separator Element Differential Pressure								
Compressor Shaft Seal Leakage	Drops/Min							
Compressor Slide Valve Position	%							
Compressor Volume Ratio	Vi							
Engine Manifold Press.	in. Hg.							
Engine Governor Oil Level	<input checked="" type="checkbox"/>							
Engine RPM								
Operating Hours	Compressor							
	Engine							
Accumulated Hours	Compressor							
	Engine							
Fluids Added (Engine oil, Comp. oil, Glycol)								

COMMENTS:

10.0 TROUBLESHOOTING

10.1 SCREW COMPRESSOR SYSTEM

Troubleshooting the compressor is limited to identifying the probable cause. If a mechanical problem is suspected, contact **Toromont Quality Compressor Services**.

SYMPTOM	PROBABLE CAUSES	CORRECTIONS
Compressor high discharge pressure.	Discharge pressure control valve.	Check PCV for correct set point and operation.
	Blockage in the discharge line.	Check all valves.
	Restricted coalescing elements.	Inspect and replace coalescing elements. Investigate problem.
	Compressor bypass in operational.	Check auto bypass valve (if equipped).
Compressor high discharge temperature.	Oil temperature too high.	Check compressor oil circuit.
	Discharge pressure too high.	Troubleshoot high discharge pressure.
	Insufficient oil injection.	Increase oil injection valve setting.
	Incorrect compressor Vi setting.	Contact Toromont Quality Compressor Services
Compressor high oil temperature.	Dirty oil cooler.	Clean oil cooler.
	Fin-fan exchanger dirty or louvers closed.	Clean and check louver and control system for correct operation.
	Insufficient air movement.	Check fan pitch and belts.
	Insufficient glycol flow.	Inspect coolant level. Inspect glycol pump.
	Glycol system air locked.	Purge air from highest point in system.
	Oil temperature control valve stuck.	Repair or replace element.
Compressor low oil injection differential pressure.	Dirty oil filters.	Replace oil filters.
	Restriction in compressor oil circuit.	Inspect oil cooler, piping, valves and oil contamination.
	Low compressor differential pressure.	Lower suction pressure. Check discharge PCV for too low a set point and proper operation.
		Check engine fuel gas valves for proper orientation.
Compressor low suction pressure.	Low suction pressure.	Increase suction pressure.
	Incorrect suction set point.	Check low suction shutdown set point.
	Suction control valve too slow or stuck.	Check suction control valve for operation and restriction.
	Compressor is loaded too much.	Unload compressor.

SYMPTOM	PROBABLE CAUSES	CORRECTIONS
Compressor oil high differential pressure.	Dirty oil filters.	Change oil filters.
	Restriction in compressor oil circuit.	Inspect oil cooler, piping, valves and oil contamination.
	Compressor oil temperature too low.	Warm up building, compressor oil and equipment.
	Compressor oil injection flow too high.	Pinch oil injection valve.
Compressor shaft seal leaking	Excess of 10 drips/minute.	Contact Toromont Quality Compressor Services
	Compressor oil contamination/dilution.	
	Shaft seal stuck.	
	Lack of lubrication.	
	Compressor internal failure.	
Excessive noise and vibration	Insufficient oil injection	Adjust main oil injection valve
	Coupling loose on compressor shaft	Tighten coupling. Replace if damaged.
	Engine to compressor misalignment	Realign engine and compressor.
	Liquid slug in suction line	Check suction scrubber for high level. Correct system problem.
	Engine misfiring or running rough	Contact Toromont Quality Compressor Services.
	Compressor wear or bearing damage	
	Excessive compressor rotor endplay	
Compressor does not load/unload.	Compressor hand-wheel failure.	Contact Toromont Quality Compressor Services.
	Compressor slide valve malfunction.	
Low jacket water level.	Air in the glycol system.	Purge air from highest point and top up glycol.
	Leaks in glycol system.	Identify leaks and repair.
Low turbo water level. (200 hp and 325 hp only)	Air in the glycol system.	Purge air from highest point and top up glycol.
	Leaks in glycol system.	Identify leaks and repair.
Suction scrubber high level	Dump system not working.	Check and/or replace automatic dump valve.
	Level controller malfunction.	Check sensitivity, presents of float or replace defective switch.
	Free liquid in inlet gas.	Source options for removing liquids.

10.2 OIL SEPARATOR SYSTEM

SYMPTOM	PROBABLE CAUSES	CORRECTIONS
Compressor oil loss.	Maintaining too high an oil level.	Lower oil level.
	Contaminated oil.	Replace oil charge
	Damaged/not seated coalescing elements.	Inspect, tighten down or replace. Check gaskets or O-rings.
	Oil return valve closed..	Open return valve
	Oil return line plugged.	Clean strainer and needle valve.
	Oil foaming.	Check oil contamination.
Increase in oil level during initial start up.	Normal behavior.	Oil is aerated.
		Retention time for gas bubble dispersion.
		Oil volume increases when temperature rises.
Increase of oil level, while running	Excessive foaming.	Check compatibility of gas with compressor oil.
	Condensing of liquids in the oil separator.	Check for correct discharge temperature and pressure and compare to gas dew points.
		Check compatibility of gas with compressor oil.
	Liquid carry over.	Troubleshoot for high suction scrubber level.
Rapid loss - no oil showing in the return sight glass.	Suction check valve did not close on shutdown.	Repair or replace check valve.
	Coalescing elements loose/not seated.	Check gaskets or o-rings.

10.3 FULL TIME OIL PUMP SYSTEM (IF APPLICABLE)

SYMPTOM	PROBABLE CAUSES	CORRECTIONS
Main filter pressure drop is too high	Dirty oil filters.	Replace oil filters.
	Compressor oil is too cold.	Warm up building, compressor oil and equipment.
	Isolation valves are partially closed.	Open valves fully.
Noise and vibration	Pump strainer plugged.	Clean strainer.
	Pump is worn out.	Repair or replace pump.
Oil pressure drops as the Discharge pressure increases	Normal behavior.	Set main oil injection and oil pressure for max. head pressure.
Oil pressure rapidly drops off when compressor starts.	Main oil injection valve too wide open.	Set valve for ½ turn open.
	Oil pressure regulator improperly adjusted.	Adjust regulator.
Pump will not produce enough oil pressure to start compressor	Oil filters are plugged.	Check PSID across filters.
	Strainer is plugged.	Clean strainer.
	Main oil injection valve open too wide.	Set valve for ½ turn open.
	Pump regulator set too low or stuck open.	Readjust or repair regulator.

11.0 APPENDIX I

11.1 FRICK Vi REFERENCE

11.1.1 XJF 151mm Vi Selection (90 hp & 135 hp)

The Vi for this model of screw compressor has 3 (field adjustable) fixed settings. **Toromont Process Systems** ships the Frick (90 hp & 135 hp) units in a 3.5 Vi setting. Compressor oil pressure and a selection of oil gallery gaskets are utilized for Vi control. The oil gallery gaskets are located behind 2 square blind flanges near the compressor shaft end.

CAUTION

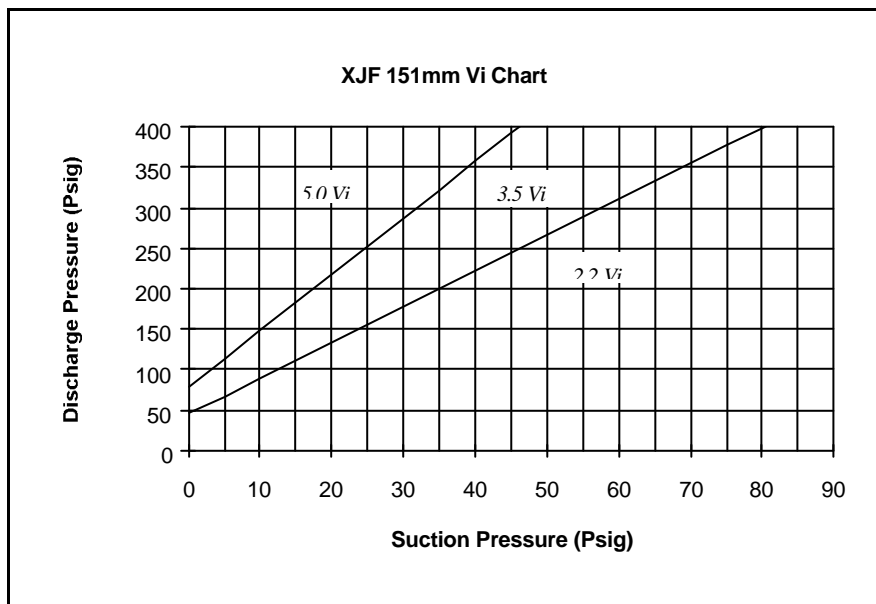
Too many rotations of the hand-wheel can overcome the oil pressure controlling the Vi and force the compressor into a lower setting. This does not affect the 2.2 Vi setting (See 11.1 Table 1) for approximate hand-wheel rotations (0% to 100% load).

ATTENTION:

Improper Vi setting can result in low flow, high temperatures, wasted horsepower and possible vibration concerns. When choosing a Vi setting, it is always more economical to under-compress than over-compress.

Procedure

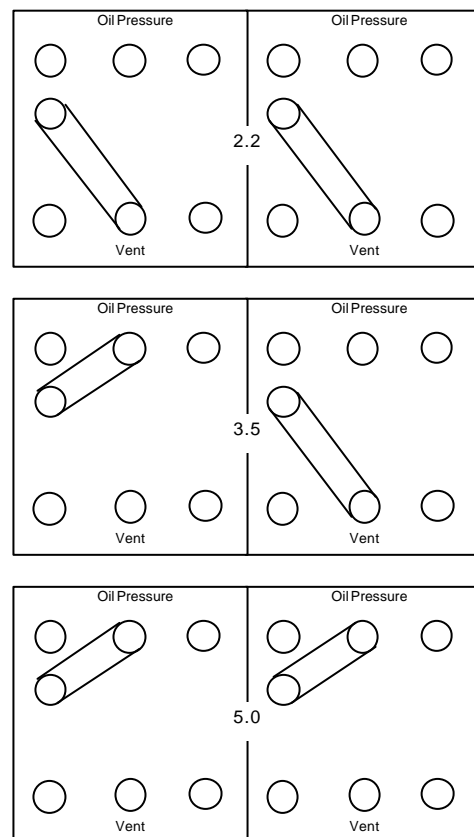
1. Determine Vi setting corresponding with site conditions (See 11.1 Figure 1).
2. Chose appropriate oil gallery gaskets (See 11.1 Table 1).
3. Identify oil gallery gasket lay out (See 11.1 Figure 2).
4. Determine Vi setting of compressor and adjust accordingly.



11.1 Figure 1

0% to 100% Load			
Vi Position	Approximate HW Rotations	Gasket Part #	Qty
2.2	30	534B0435H01	2
3.5	21	534B0435H01	1
		534B0436H01	1
5.0	17	534B0436H01	2

11.1 Table 1



11.1 Figure 2

11.1.2 TDSH 193S thru 283SX Vi Selection (200 hp & 325 hp)

These models of screw compressors have 4 (non-field adjustable) fixed Vi settings. All **Toromont Process Systems** (200 hp & 325 hp) units are shipped in a 2.2 Vi setting. *No Vi-ring installed unless otherwise noted on P&I drawings and/or project BOM.* A steel Vi-ring must be machined and installed in order to change this fixed setting (See 11.1 Figure 4). The operation requires dismantling the compressor slide valve assembly.



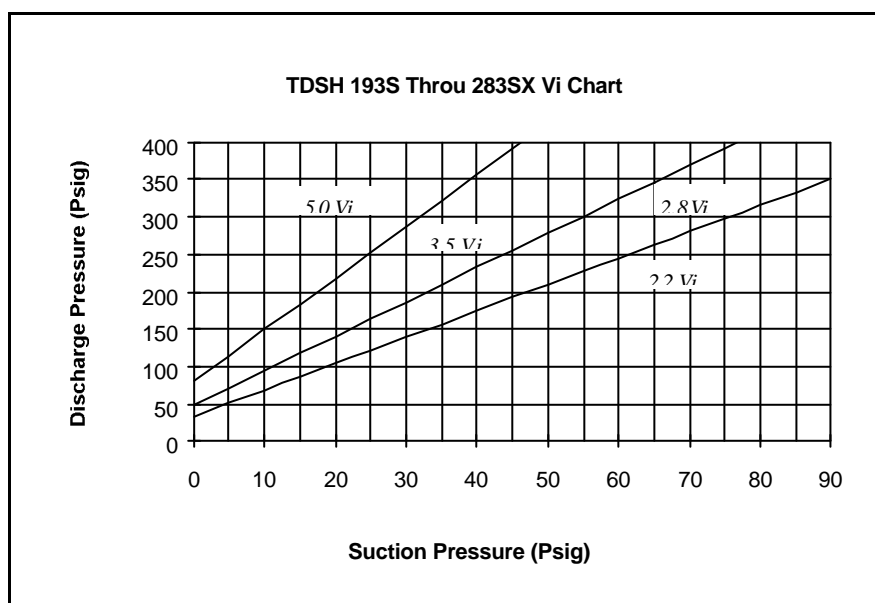
Only qualified personnel should perform the Vi-ring installation. Improper dismantling of the slide valve assembly can cause serious injury.

ATTENTION:

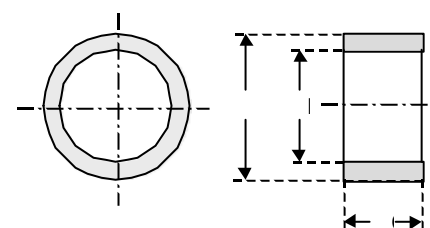
Improper Vi setting can result in low flow, high temperatures, wasted horsepower and possible vibration concerns. When choosing a Vi setting, it is always more economical to under-compress than over-compress.

Procedure

1. Determine Vi setting corresponding with site conditions. (See 11.1 Figure 3)
2. Inspect Vi indicator rod to verify compressor Vi setting.
3. Vi indicator rod is approximately:
 - a) 3/4" length in a 2.2 Vi.
 - b) 9/16" length in a 2.8 Vi.
 - c) 3/8" length in a 3.5 Vi.
 - d) Flush with nut in a 5.0 Vi.
4. Contact Toromont Quality Compressor Services to perform Vi adjustment.



11.1 Figure 3



11.1 Figure 4

11.2 ARIEL Vi REFERENCE

11.2.1 Ariel AR-166 & AR-208 Vi Selection (90 hp & 135 hp)

The Ariel screw compressors have 4 (field adjustable) fixed Vi settings. **Toromont Process Systems** ships the Ariel (90 hp & 135 hp) units in a 4.8 Vi setting. *No Vi-ring installed unless otherwise noted on P&I drawings and/or project BOM.* Ariel supplies each compressor with a toolbox containing the Vi-rings (See 11.2 Figure 2). Vi-rings are stamped with their appropriate Vi setting and are installed between the hand-wheel housing and compressor casing.

CAUTION

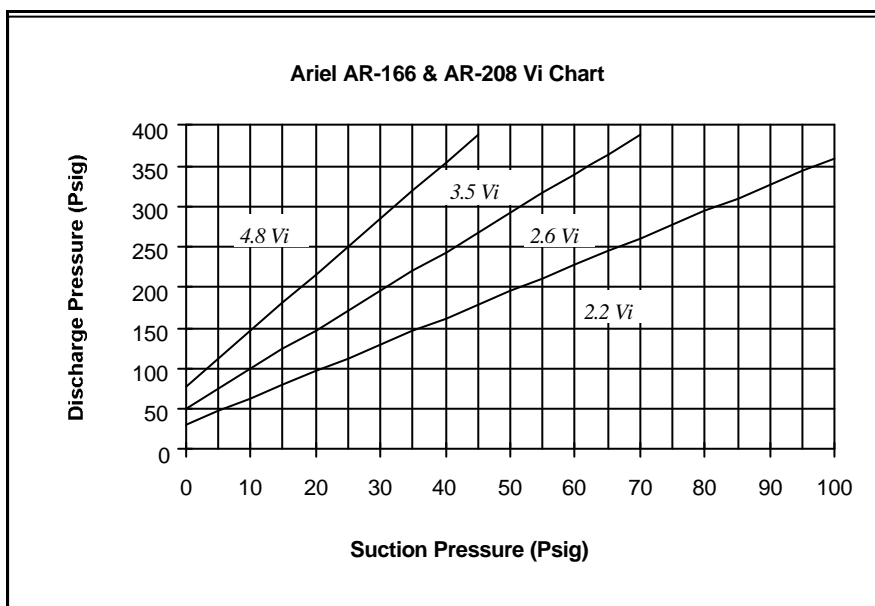
For each Vi-ring there is a dowel pin and a set of corresponding, length bolts. Compressor damage can result if proper equipment is not installed.

ATTENTION:

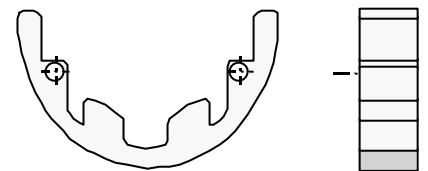
Improper Vi setting can result in low flow, high temperatures, wasted horsepower and possible vibration concerns. When choosing a Vi setting, it is always more economical to under-compress than over-compress.

Procedure

1. Determine Vi setting corresponding with site conditions. (See 11.2 Figure 1)
2. Identify compressor Vi setting by noting which Vi-ring is installed.
3. Install the proper V-ring for site conditions.
4. Adjust Balance Line oil pressure. See *Balance Line charts*



11.2 Figure 1



11.2 Figure 2

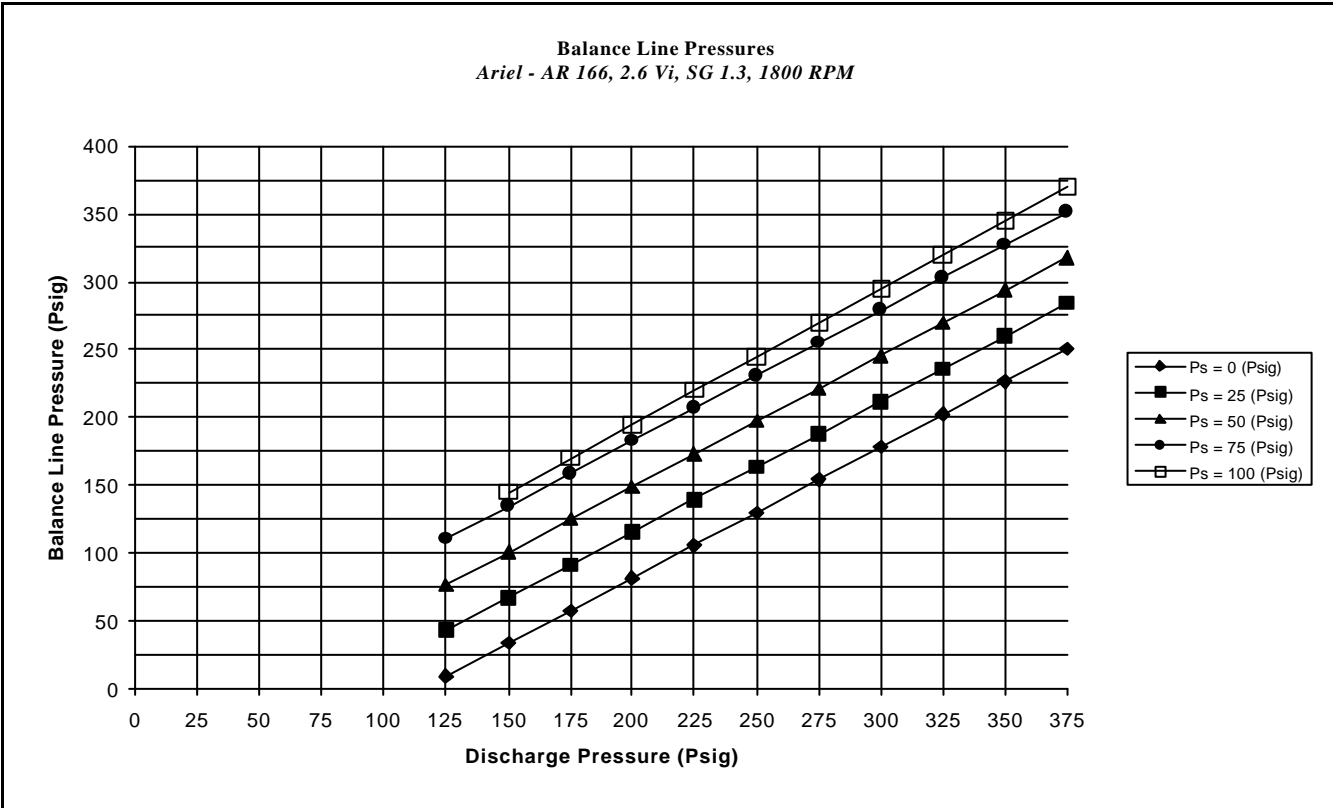
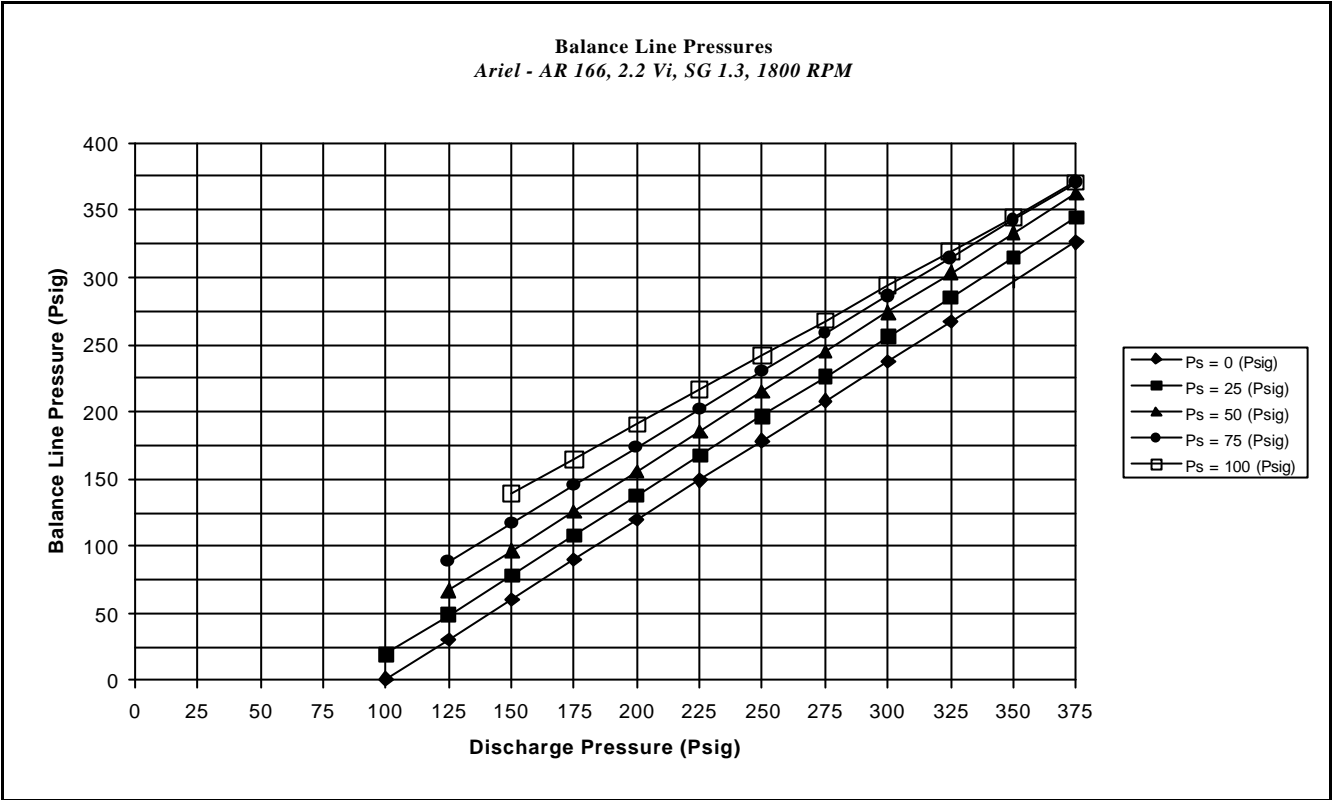
11.3 ARIEL BALANCE LINE CHARTS

Ariel compressors utilize gas balancing to extend life of the male thrust bearing. Discharge pressure is piped around to suction end, which acts on a piston area and creates a force opposing the normal thrust force. Normal thrust direction, caused by differential pressure and helix angle, is from discharge end to suction end. Adjust the Balance Line Pressure according to compressor model, site conditions and Vi setting using the following Balance Line Charts.

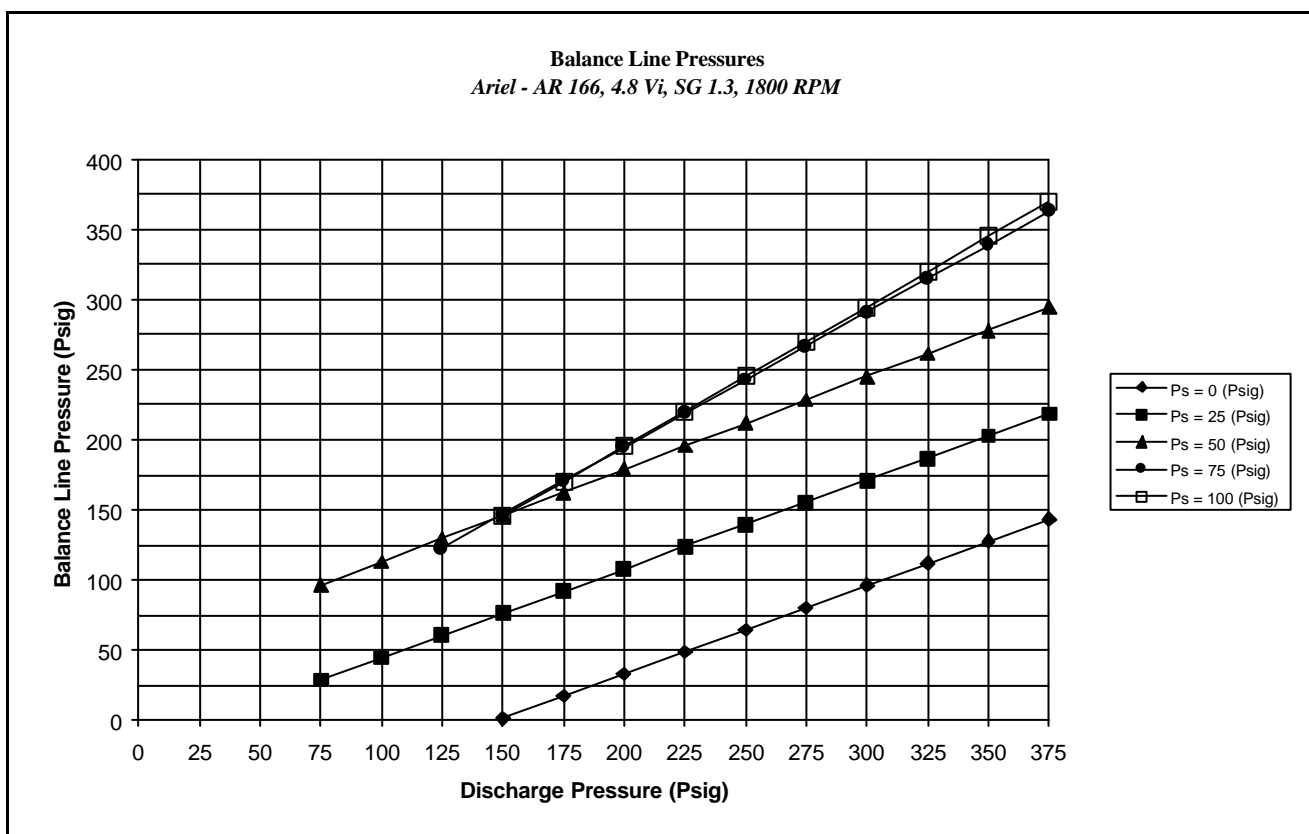
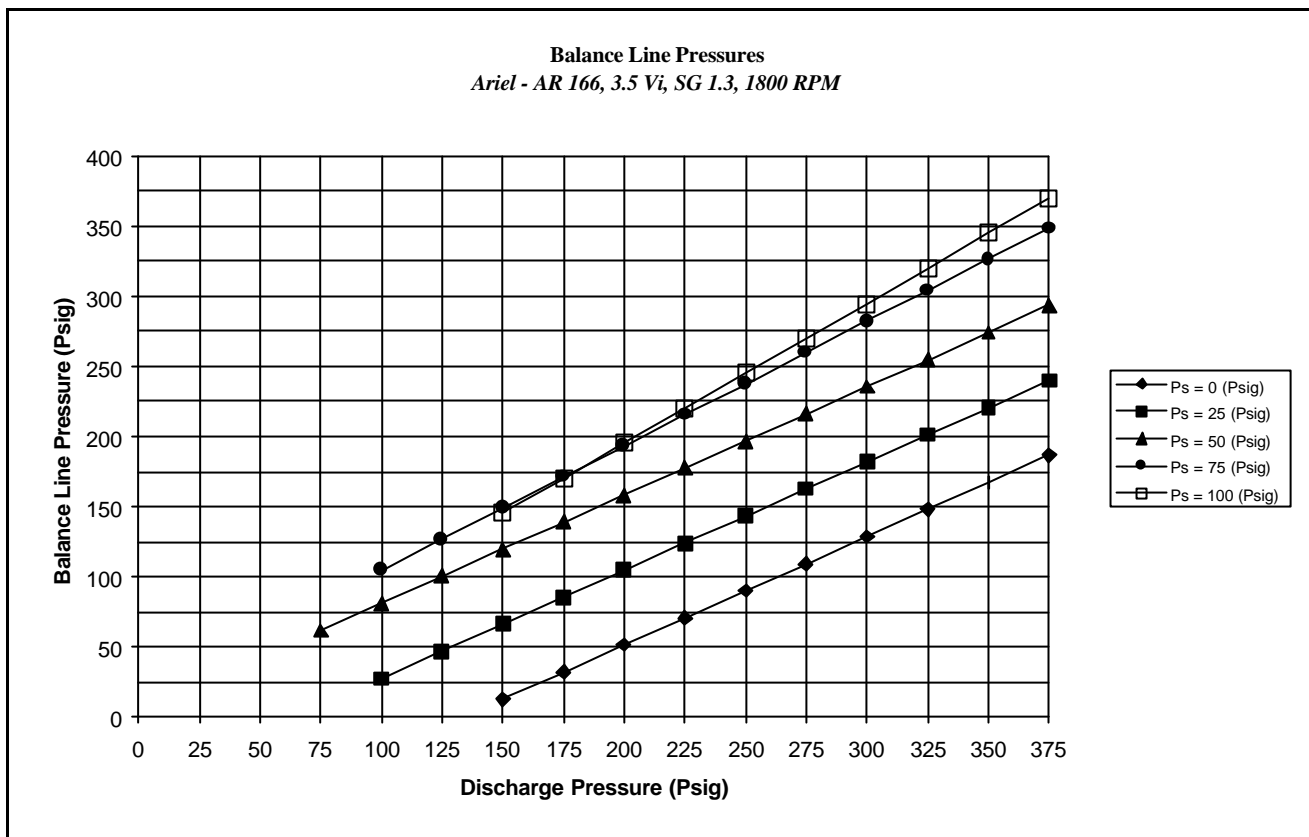
CAUTION

Premature male thrust bearing failure can occur if the balance line pressure is not adjusted for each change in package operation and site conditions.

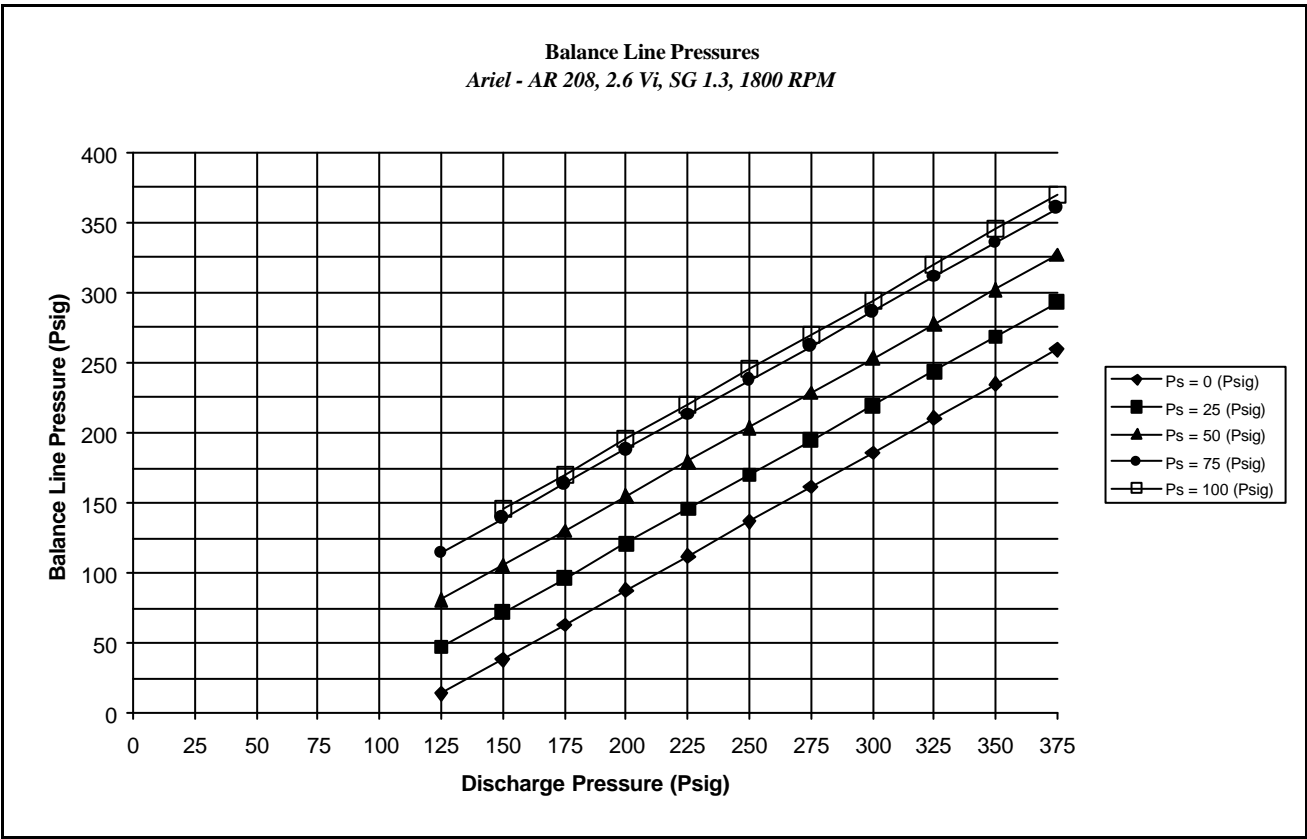
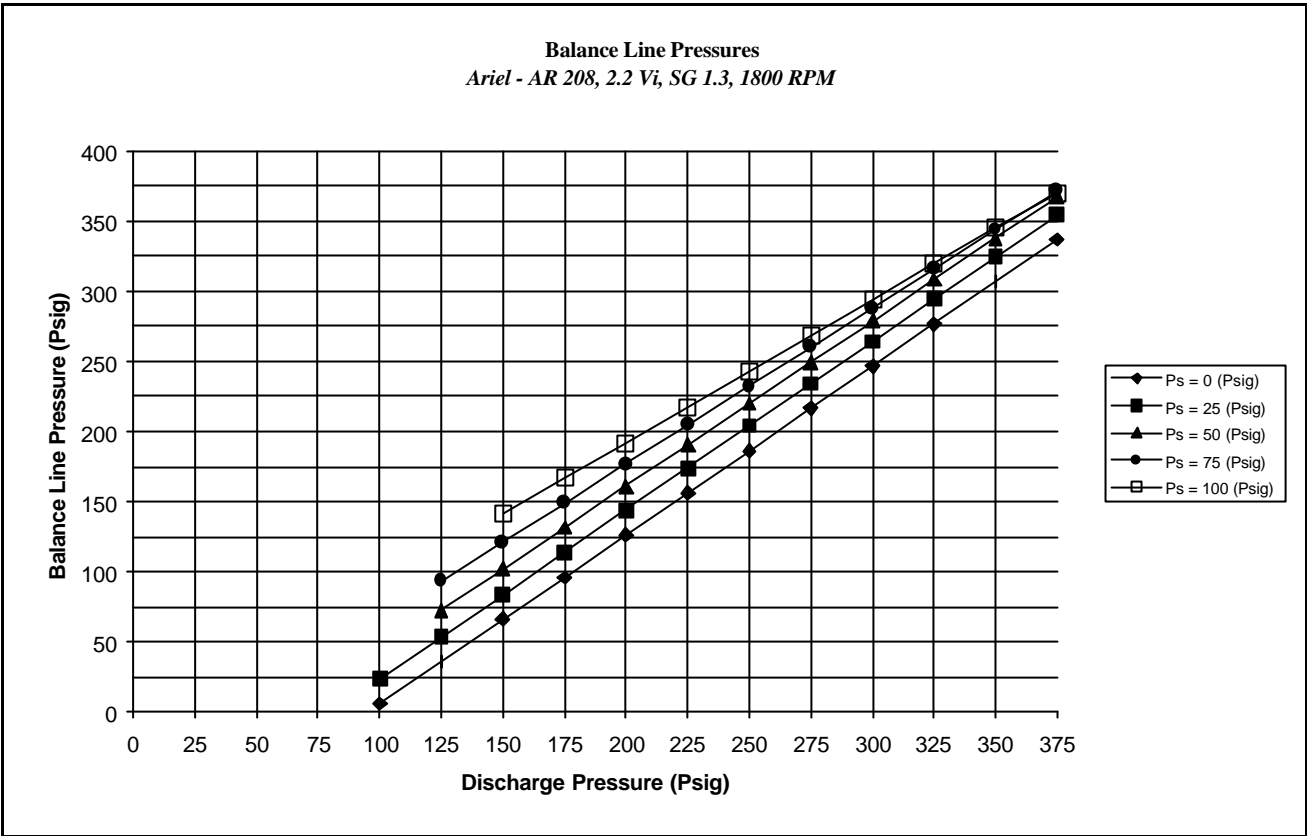
11.3.1 Ariel AR-166 Balance Line Charts



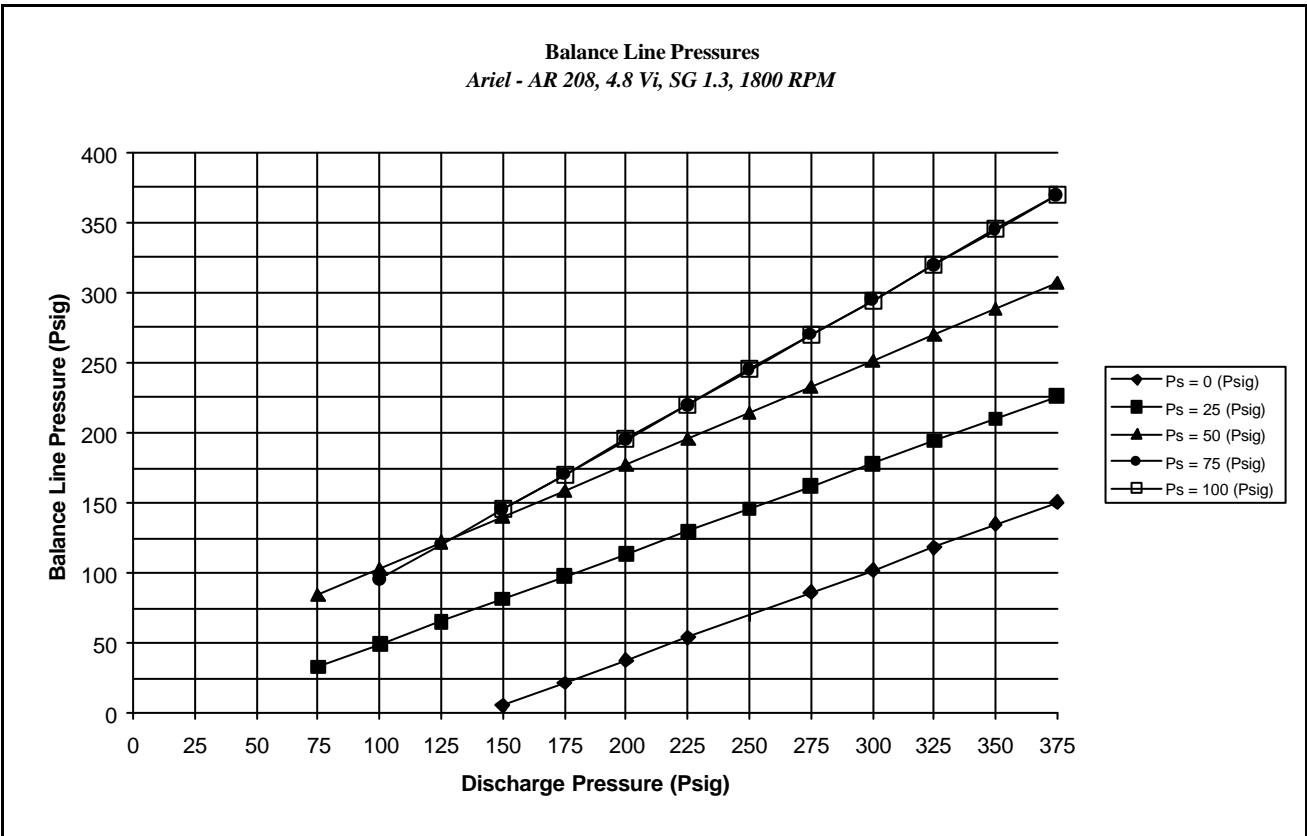
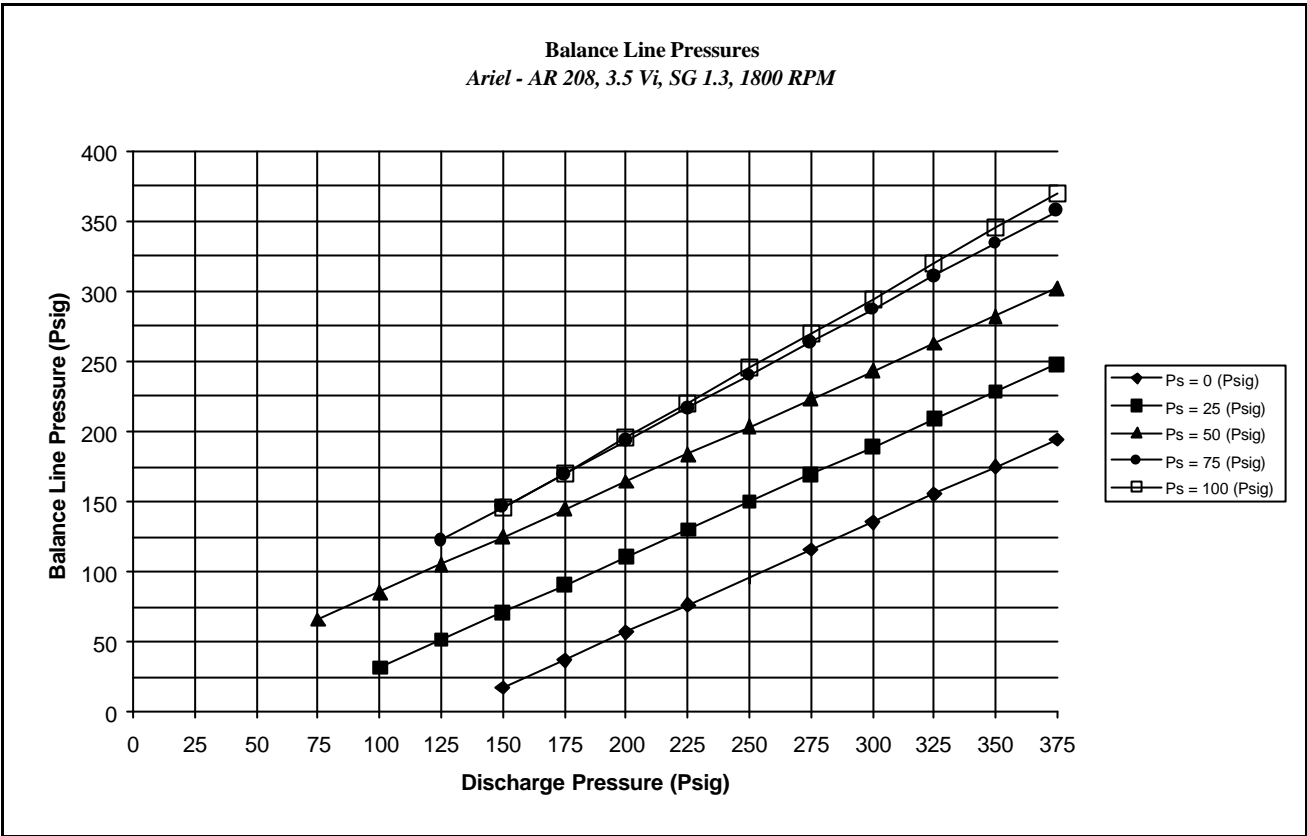
11.3.2 Ariel AR-166 Balance Line Charts Cont.



11.3.3 Ariel AR-208 Balance Line Charts



11.3.4 Ariel AR-208 Balance Line Charts Cont.



11.4 BACK PRESSURE CONTROL VALVE

11.4.1 Frick XJF 151mm (90 hp & 135 hp) ONLY:

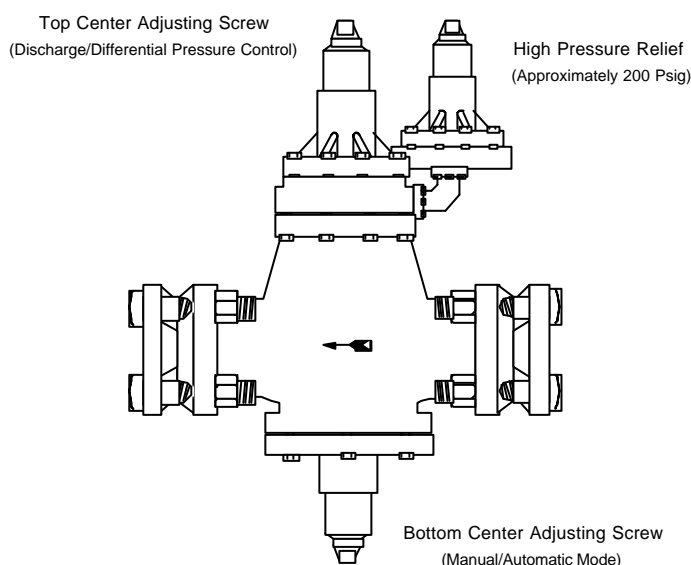
Toromont Process Systems 90 hp and 135 hp packages that are supplied with Frick XJF 151mm compressors do not have an oil pump. Compressor oil pressure is achieved through the differential between suction and discharge pressures. A **Back Pressure Control Valve** has been supplied to artificially create sufficient pressure differential for the site operating conditions that do not create this differential naturally (See 11.4 Figure 1). The backpressure control valve is located downstream of the secondary oil separator, prior to the fin-fan cooler. If site-operating conditions do not offer sufficient differential to satisfy the compressor oil pressure logic, this valve must be properly adjusted and put into operation.

Valve component identification:

1. The small regulator off to the side is a high-pressure relief.
2. The adjusting screw on the bottom center of the main valve is the automatic/manual adjusting screw.
 - a) All the way in is automatic mode.
 - b) All the way out is manual mode (valve is open, no regulation).
3. The adjusting screw on the top center of the main valve is for setting the discharge/differential pressure.

Procedure for adjusting:

1. Adjust engine to 1800 RPM and load the machine to approximately 30% to achieve differential pressure.
2. Turn the high-pressure relief in all the way.
3. Turn in the top center adjusting screw to achieve 200 Psig discharge.
4. Turn out the high-pressure relief until it just starts to relieve @ 200 Psig.
5. Go back to the top center adjusting screw and turn out to lower discharge to achieve approximately 10 Psig differential above differential shutdown.



11.4 Figure 1

12.0 APPENDIX II

12.1 RENTAL UNITS

12.1.1 Toromont Process Systems Responsibility

Toromont Process System is responsible for providing equipment that is mechanically sound and in good operating conditions to each rental equipment end user.

12.1.2 End User Responsibilities

To inform **Toromont Process System** if the compressed gas stream contains any H₂S, or unusually large amounts of N₂, CO₂, air, condensates or heavy hydrocarbons.

The end user is responsible for the maintenance of, but not limited to the following:

1. All normal lubrication requirements
2. All belts, hoses, etc.
3. All ignition, carburetor and tune-up requirements
4. All alignment subsequent to start up
5. All packing, compressor piston rings, valves and mechanical seals
6. All compressor cylinders or rotors and housing
7. All cooler maintenance
8. Control panel, controls and instruments
9. All accessories, e.g.: Heaters, check valves, etc.
10. Building

In addition, the end user shall be responsible for any costs incurred due to any of the following:

1. Damage in transportation
2. Improper operation
3. Improper maintenance
4. Improper storage
5. Site conditions
6. Improper fuel gas (if not specifically authorized by **Toromont Process Systems**)
7. Poor gas quality
8. Improper mounting of skid
9. All others as per rental agreement

12.1.3 Operators Responsibilities

The Field Operator shall be responsible for the following:

1. Daily maintenance included maintaining proper fluid levels
2. Routine checks of compressor operations including temperatures and pressures.
3. Prompt reporting of any problems to **Toromont Quality Compressor Services**
4. Reasonable access to location.
5. A key to any locked gate must be furnished to **Toromont Quality Compressor Services**.
6. Completion of daily operating records.
 - a) Forward copy to **Toromont Quality Compressor Services**
7. Oil sampling as requested by **Toromont Quality Compressor Services**

12.2 FIELD PRE-SHIPMENT PREPARATION

1. All bills of lading will include the legal land description (LSD) where the unit had been operating. This description is required if it becomes necessary to dispose of waste petroleum products (eg. Condensates that were missed during the field cleanup).
2. Identify the type of service the equipment was in (eg. Sour, sweet, propane, CO2 etc.).
3. Specific notes:
 - a) Glycol coolants may remain in the main and auxiliary systems, including oil cooler and inter cooler housing, provided there are no visible external leaks. ***On Toromont Process Systems leasing units only. All other units must be drained.***
 - b) Engine/compressor crankcases and on skid oil storage/make up tank DO NOT require draining. ***On Toromont Process Systems leasing units only. All other units must be drained.***
4. Drain requirements:
 - a) Vacuum pump waste oil from on skid waste oil storage tanks
 - b) Vacuum pump waste products from on skid compressor packing vent/drain tanks.
 - c) Drain all liquids from inlet separators/coalescing filters.
 - d) Drain all fluids from inter-stage/final discharge separators.
 - e) Drain oil bath air cleaners
 - f) Purge the process system, including gas cooler sections using an inert gas (eg. Nitrogen).
5. All open flanges **with the exception of the PSV vent header** to be hard flanged complete with gasket. All NPT screwed connections to be capped or plugged. The PSV vent header is to be sealed with plastic wrap to allow for the relief of pressure should a buildup occur
6. Engine intake and exhaust openings to be sealed off with plastic.

12.3 MOUNTING SKID (Responsibility of End User)

12.3.1 General:

To determine the type of skid mounting that is required the following steps should be taken:

1. A civil engineer should be consulted in the preparation of any foundation or pad design for the unit.
2. It is always recommended to perform a geo-technical investigation of the sub-surface conditions of the installation site.

12.3.2 Piles:

1. It is the end users responsibility to place the piles as recommended by a Civil Engineer and to determine the pile diameter and depth based on the soil conditions.
2. It is important to support the skid primarily down the center members and under the rotating equipment, as well as the perimeter.
3. Skid must be shimmed level and provide good contact with pile cap
4. Skid deflection can cause alignment problems, pipe strain and vibration. Once equipment has been placed on pile caps, equipment must be checked for alignment and pipe strain. Align if required.
5. As a minimum 3 sides of pile cap should be welded to the skid member.

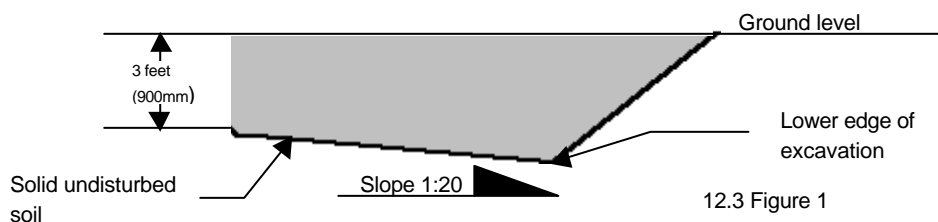
12.3.3 Timbers

It is not recommend placing the skids on timbers due to the irregularities in both the skid base and the timbers.

12.3.4 Gravel Pad

Excavation

- a) The gravel pad is to be excavation to the Horizontal limits of the skid and depth as shown in 12.3 figure 1. If water or frozen soil is exposed, remove those areas as well until firm undisturbed or compacted soil is exposed.
- b) Bottom of excavation is to be proof rolled in two directions prior to placement of gravel fill. Should this process reveal any soft areas, they will have to be:
 - i. Removed
 - ii. Exposed soil loosened (at least 6" (150 mm) deep)
 - iii. Compact loosened area
 - iv. Back fill with gravel.
- c) The finished excavation should be crowned along centerline of the skid and sloped downward to a ratio of 1:20 to the edge of the excavation.



ATTENTION:

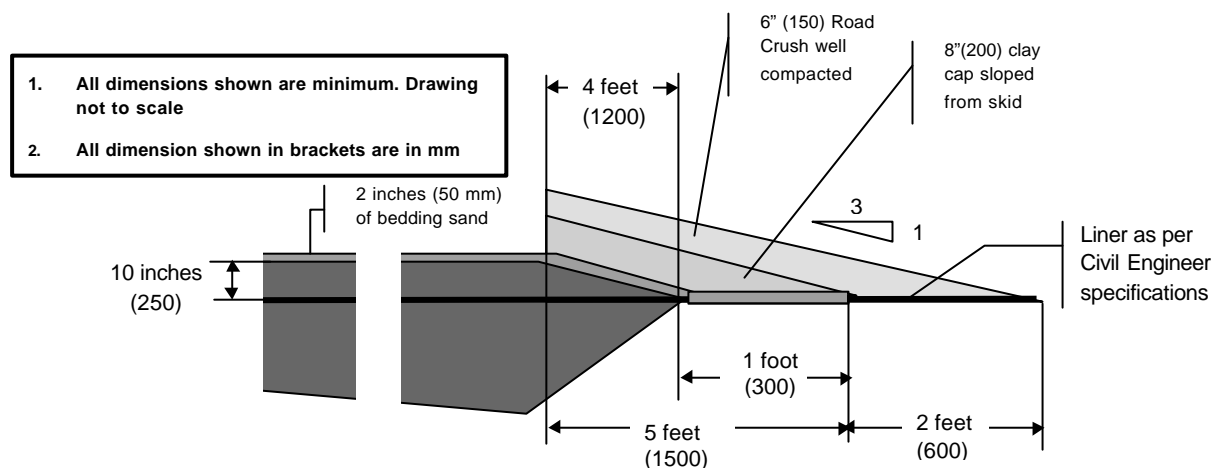
The excavation should be protected from rain, snow & ingress of free water.

Gravel Fill and Finish

- a) Gravel (maximum $\frac{3}{4}$ inch (19 mm)) fill used is to be clean and well graded, unfrozen, non-frost susceptible material. The Gravel fill is to be sampled & tested to environmental conditions prior to placement.
- b) The excavated area is to be filled with sections of 6 inches (150 mm) gravel fill and compacted to a uniform dry density of no less than 100% standard Proctor maximum dry density.
- c) Compaction is to be done by a self-propelled, smooth drum, vibratory compactor. Having a drum width of not less than 56 inches (1420 mm) wide & a gross weight not less than 11,500 lbs (5,200 kg).
- d) Provide clay cap & finish gravelling as detailed.
- e) The pad should be level and even, to ensure proper operation of the unit.
 - i. Place unit on pad
 - ii. Remove unit from pad and evaluate imprint
 - iii. Fill in low spots with sand and compact
 - iv. Slide compressor to final location

ATTENTION:

Unnecessary prolonged exposure of the foundation to the elements is to be avoided and ponding should not be allowed.



12.3 Figure 2

13.0 APPENDIX III

13.1 SPECIAL INSTRUCTIONS